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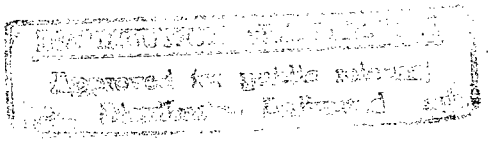

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INDUSTRIAL TECHNOLOGY, PLANNING, PRODUCTIVITY

Characteristics of Coupled Heat-Mass Transfer During Supersonic and Hypersonic Flow of Streams Past Blunt Bodies

937F0081B Tomsk IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: FIZIKA No 8, Aug 92 pp 82-95

[Article by V.I. Zinchenko; UDC 533.526:536.24]

[Abstract] The problem of coupled heat-mass transfer between gas and solid with attendant chemical reactions in the gaseous phase is formulated for axisymmetric or three-dimensional supersonic flow past blunt bodies with a boundary layer or a viscous shock layer at their surface. The proposed model is simpler than the original (A.V. Lykov and T.L. Perelman, 1965; A.V. Lykov, 1972; A.M. Grishin, 1973; A.M. Grishin and V.M. Fomin, 1984) shock layer at the surface of blunt bodies and is shown to be not only adequate but also sufficiently universal, inasmuch as in a gas stream carrying solid particles both Reynolds number $N_{Re,\infty}$ and the Mach number $N_{Ma,\infty}$ of quiescent flow (at "infinity") can vary over wide ranges. The system of Navier-Stokes equations for the most general case of a shock layer of a reactant mixture is accordingly formulated in a system of nonorthogonal curvilinear coordinates affixed to the body surface, the model then being reducible not only to intermediate models of thin viscous and paraboloidal shock layers but also to a model of three-dimensional boundary layer and to the Euler model. The appropriate boundary conditions for an incident shock wave are the generalized Rankine-Hugoniot relations accounting for diffusion and heat conduction, these relations being derived from general conditions at the surface of nonremovable discontinuity by disregarding 0-order terms and assuming that chemical reactions are "freezable" in time. The characteristics of coupled heat-mass transfer are evaluated accordingly, taking into account that nonuniform heating of the surface results in a nonuniform distribution of the relative Stanton number $N_{St}/N_{St,0}$ (N_{St}- Stanton number, $N_{St,0}$- its value at the stagnation point) and this effect being evaluated by the method of successive approximations as has been done for a laminar boundary layer. For the case of turbulent flow are used Sebesy-Clausius models covering a wide range of gas flow rates and found to be consistent with experimental data. The results of numerical calculations for a three-dimensional viscous shock layer at convexly blunt surfaces indicate that the model of a thin viscous shock layer combined with global iterations regarding the form of the shock front should be adequate for solutions of coupled heat-mass transfer problems. Figures 5; references 40.

Simulation of Two-Phase Flow Through Channels and Nozzles

937F0081A Tomsk IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: FIZIKA in Russian No 8, Aug 92 pp 71-81

[Article by I.M. Vasenin, A.A. Glazunov, N.Ye. Kuvshinov, R.K. Narimanov, V.A. Ivanov, and S.V. Shpigunov; UDC 523.52:662.61.532.529: 538.4]

[Abstract] Flow of a two-phase mixture in combustion chambers of solid-fuel rocket engines is analyzed, a mathematical model being constructed which facilitates solution of the flow problem by computer-aided numerical simulation. The concentration of combustion product particles in the stream is assumed to be sufficiently low to render negligible their influence on the gaseous phase and the Mach number is assumed to be small enough for the flow of gas to be treated as that of a nonviscous fluid. The problem is formulated as one of axisymmetric flow: the gas stream carrying solid particles enters a cylindrical chamber from all around through the permeable lateral wall and converges through the open end of this chamber into a nozzle with an also impermeable wall, the other end of the chamber being closed by an also impermeable wall. The medium of monodisperse particulate metallic fuel and monodisperse particulate combustion product (metal oxides) in the chamber satisfies the two respective equations of motion for each and the continuity equation covering both, with the appropriate boundary conditions. These equations are solved analytically for both axial and radial profiles of flow parameters as functions of time till complete combustion, then specifically for burning aluminum particles. Next is considered steady off-equilibrium flow of a gas carrying a polydisperse liquid condensate through a deLaval nozzle, coagulation and fragmentation as well as rotation of particles being included in accordance with the multifluid model of a continuous medium and its system of equations. Another kind of solid-fuel engine are pulsed MHD-generators using metallized plasma-forming fuel, its combustion products also forming a two-phase mixture but containing more condensate than that in rocket engines. In this case is considered three-dimensional flow of a two-phase plasma from its generator into a gas-dynamic power system: through a subsonic nozzle and a supersonic one into the expanding rectangular MHD-channel followed by a diffuser. The two electrodes covering two opposite walls of the MHD-channel are assumed to be ideally conducting and the other two channel walls to be isotropic. The magnetic induction in this channel is assumed to have only a transverse component with an arbitrary longitudinal profile. The flow in such a system is also described in accordance with the multifluid model of a continuous medium, but with the electric field intensity vector and the current density included in its system of equation. Conventional assumptions regarding nozzles are supplemented here with three others: 1) that all solid particles in the stream are electrically neutral; 2) that both electrical conductivity of the medium and electron mobility depend only on the characteristics of the gaseous phase; 3) that the coefficients of thermal, mechanical, and rotational interactions do not depend on the electric field intensity. Figures 11; references 15.

Adaptive Algorithms for Damping Short-Period Aircraft Vibrations. Lengthwise Motion

937F0107A Moscow VESTNIK MOSKOVSKOGO GOSUDARSTVENNOGO TEKHNICHESKOGO UNIVERSITETA: SERIYA PRIBOROSTROYENIYE in Russian No 3, Jul-Sep 92 (manuscript received 1 Nov 91) pp 76-88

[Article by P.D. Krutko, A.A. Malakhov, and V.G. Chernyshov; UDC 697.7.05.001]

[Abstract] A method has been proposed for synthesizing adaptive algorithms for damping short-period vibrations of an aircraft during the course of its lengthwise motion. The algorithm is synthesized by solving problems of minimizing the instantaneous values of the acceleration energy by the controlled variable. In other words, the pitch channel damper is constructed on the basis of a loop controlling the peripheral velocity around its transverse axis. The functional undergoing minimization is formulated in the vicinity of the trajectory of the motion of a standard model with dynamic characteristics meeting the requirements set for the dynamics of the system being designed. The new damping algorithms have an unconventional structure that in turn has a low sensitivity to changes in parameters and the effect of external disturbing forces. This is accomplished by using identification, estimation of state coordinates, and adaptation. The application of the proposed algorithm is illustrated by way of the example of an analysis of the dynamics of the motion of a supersonic light aircraft in five different flight modes (at low, medium, and high altitudes with different velocities). The new algorithm is demonstrated to provide a rather high degree of stability of dynamic damping characteristics in each of the very different flight modes considered. The problem of compensating for disturbances in a damping loop is also considered. The mathematical model presented confirms that a damping system based on the proposed algorithms quickly acquires the trait of natural adaptivity. Figures 4, table 1; references 5 (Russian).

Recommitment to Nuclear Power Backed

93WN0250C Moscow KRASNAYA ZVEZDA in Russian 27 Jan 93 p 2

[Article by Mikhail Rebrov, KRASNAYA ZVEZDA, in the "Point of View" column: "Nuclear Power Stations Without Fear or Illusions"]

[Text] **According to ancient mythology, "the world rests on three pillars." However, previously these were imagined to be giant elephants, turtles, or whales, whereas at present, real life leaves no doubt that energy, ecology, and the economy are the three pillars on which human civilization rests. If any one of them is destroyed, catastrophe is unavoidable.**

Literally at the finish line of last year (on 28 December), the government of Russia adopted Decree No. 1026 on the construction of nuclear power stations on the territory of the Federation. It actually amounts to a program for the development of power generation for the period until the year 2010. Will it be translated into reality?

That we live in an environment of paradoxes hardly comes as a surprise to anyone at present because dogmas about the "unity and struggle of opposites" have been drummed into us from childhood. This is perhaps the source of a contemplative or even altogether indifferent attitude toward the fact that, in their region, the residents of Rostov are heatedly protesting against an AES [nuclear power station], since they have not experienced a power shortage, whereas the residents of Yerevan are demanding, just as stormily, that the once shut-down nuclear power station be brought back to life. This appears to be a strange situation. However, it reveals the profound meaning of what is happening: Things are on occasion naively interpreted, and on occasion, reflect the ambitions if not the incompetence of participants in rallies.

Indeed, the tragedy of Chernobyl has caused mass radiophobia and brought about the militant rejection of nuclear power generation and the widespread conviction that it would be better to go back to "kindling and dung cakes" as long as the frightening AESs are not around. However, let us reason: What will happen if all nine AESs in Russia, with their 28 power units, are shut down? What does our society stand to lose by virtue of this? Let us start with specific examples, without which it is difficult to shed both illusions and fear.

At present, the per capita consumption of primary energy resources in our country amounts to 6.7 tons of standard fuel a year (for comparison, in Western Europe it is 5 tons, and in the United States—11 tons). The energy sector claims from the national economy approximately one-quarter of all capital investment and one-fifth of labor resources. With all of this, it barely meets the needs of our households and production facilities. So, the AESs of Russia, with a total installed capacity of 20,242 megawatts, account for more than 11 percent of the output of electricity. The total volume of fossil fuel savings comes to 40 million tons a year (incidentally, the idling of power units prepared for operation brings about losses going into millions daily).

One more point. TESs [thermal power stations] account for the bulk of electricity generation (60 percent), to which end 211 million tons of standard fuel are used, or 41 percent of the gas used in Russia, 14 percent of the oil, and 37 percent of the coal. Besides, the peculiarities of the Russian economy are such that the main energy resources are located in the eastern regions of the country, whereas the European section is responsible for about 70 percent of the total output and consumption of electricity. About 20 percent of all fuels produced are used to deliver energy to these regions. Such is the price of "nonnuclear" electricity.

More than 75 percent of energy is generated on our planet as a result of the processing of fossil fuels. In the process, 21 billion tons of carbon dioxide are emitted into the atmosphere annually, which threatens a global ecological catastrophe.

Along with our entire economy, the fuel and energy complex has great inertia because of its resource intensiveness. Production falls in 2 to 3 years (if investment is stopped), whereas it takes as many as 8 to 10 years to restore the previous volume (if additional investment is made).

As far as mothballing AESs is concerned, the picture is as follows. The gradual decommissioning of operating power units (over 10 to 15 years) will call for the additional generation of 12 to 13 percent more energy. Hydropower stations and other sources (wind, the sun, tides, and subsurface heat) will not be able to offset the deficit that emerges. So, do we use oil and gas? We have already described the price for this solution.

The fear of radiation is understandable. As early as the time of Hiroshima and Nagasaki, humanity understood what one of the greatest discoveries of science can turn into. The accidents at the American AES "Three Mile Island" and Chernobyl became yet another reminder of the latent danger. Of course, all progress, including that of nuclear power generation, entails certain risks. However, for the sake of objectivity it should be acknowledged that the unsatisfactory operation of the general industry equipment of the AESs, human error, and an inadequate level of organization of operations have become the main reasons for all the unplanned shutdowns of power units.

However, let us revisit the topic of what is going to happen if the AESs are closed down. Of course, background radiation will diminish, but only by one percent, and somewhat more on the sites of the stations proper: by five to 10 percent. At the same time, an increase in the percentage of fossil fuels to offset losses in electric energy will bring about the tremendous consumption of atmospheric oxygen, and because of the use of coal, greater background radiation as well.

This is why it is unbecoming to practice wishful thinking or give in to emotions when making decisions on energy issues. To possess energy resources and to be able to manage them properly means to have a reliable foundation for accomplishing all social tasks. The energy sector is likely to be the very sphere in which the building of a regular market economy will begin. This is why we do not need extemporaneous decisions in our AES policy (to close down, to ban, to give up, and so on), but a well-considered and scientifically justified concept for the development of nuclear power generation bolstered by ecological expert reviews, and a concept geared toward the development of new-generation technology with a qualitatively better safety level (such designs are already available).

There is no throwing obstacles in the path of scientific and technical progress. Whether we like it or not, fission-based nuclear power generation, by advancing technology and science, is blazing the trail for the wide-scale assertion of the thermonuclear power generation of the next century, as well as opening unique opportunities to directly transform nuclear energy into electricity, regenerate nuclear and thermonuclear fuel, and synthesize artificial elements endowed with necessary properties...

Since we have recently gotten used to hanging on every word of the West, I will mention their situation with AESs. In France, nuclear electricity factories account for 74.6 percent of total energy generation; in South Korea, it is 50.2 percent, in Sweden—45.1 percent, in the FRG—33.9 percent, in Japan—27.8 percent, and in the United States—20 percent. Within the same period of time, Japan intends to double power generation by AESs.

The reader might say: "However, over there everything is better and safer. They demand that our AESs be closed, and promise to help us with funding." Talk is cheap (pardon the uncultured expression). "The standard of future Russian technological solutions for AES safety is not inferior to the best Western developments, and is frequently superior..." This is a quote from official findings. Let me also recall that all our AESs have been inspected by IAEA [International Atomic Energy Agency] experts and found reliable and safe. As far as funding supposedly promised for reconstruction is concerned, so far nobody has given us a kopek, and they hardly will. Their calls "to close down" proceed from hidden benefits for themselves.

Having opened these notes, perhaps subjective in a way, with opinions on paradoxes, I would like to likewise finish with them. Russia became the first country to use the peaceful atom when it started up the AES in Obninsk as early as 1954. To this day, Russia is also the one lacking a law on the use of nuclear energy, which is supposed to provide a legal foundation for the secure development of the industry. However, even this is no reason to go back to kindling, really.

Continuation of Nuclear Construction Program Debated

Industry Spokesmen Defend Decision

93WN0251A Moscow ROSSIYSKIYE VESTI in Russian 23 Jan 93 p 5

[Article by Valeriy Marchenko and Nikolay Myakinnik published under the general heading: "The Government's Position: Construction of Nuclear Power Stations Will Continue": "Energy Professionals' Opinion: The 'Greens' Push the Energy Sector Towards the 'Red Line'"]

[Text]

The government of the Russian Federation has adopted a decree on the development of nuclear power generation which envisages continuing the building of AES [nuclear power stations] on the territory of Russia. In particular, this involves the construction of four generating units at the Balakhovo AES and one generating unit each at the Kalinin and Kursk AES.

In addition, in the near future proposals will be considered as to the time frame of the possible additional construction of a sixth generating unit at the Voronezh heat-supply nuclear power station (AST) and construction of a new AES at Yuzhno-Uralsk and Beloyarsk. It is envisaged that before summer 1995 the lead generating unit of a new-generation nuclear power station will be put on line at Sosnovyy Bor (near St. Petersburg), which will be constructed on the basis of the Leningrad AES.

It is also envisaged to conduct technical and economic research and project development for a number of AES on the territory of the Far North and the Lower Volga Area. Financing for capital investment for a number of these projects was already appropriated last year, 1992.

The "greens" are on the offensive everywhere. The effect of their actions, however, is the same as from the "scorched earth tactic." They came, they criticized—it did not help; they made a scandal—and finally got their way: the facility was closed. Afterward—who cares! For instance, the "greens" are capable of blowing the smallest incident at a nuclear station into a mind-boggling catastrophe; the conclusion is even more frightening: Let us destroy nuclear power generation in principle.

It has been noted many times that the "greens" are often imprecise and untruthful in their statements and evaluations. Take for instance the statement—with reference to the IAEA [International Atomic Energy Agency] at that—that there is a 27 percent probability of a serious accident at one of the obsolete Russian reactors. And immediately contending that allegedly all our other reactors are dangerous and declaring them unfit for any reconstruction. This is at a time when the IAEA does not accept such a position, considering the aforementioned figure frivolous. Leading specialists are against the direct use of these kind of probability evaluations for populist

purposes. By the way, international commissions also note the good quality of our reactors.

Another noticeable trait is that in addition to the errors and truth-stretching that are characteristic of the conclusions and the very activities of the "greens," their propaganda efforts also show certain one-sidedness, aimed exclusively at destruction. As a rule, they persistently attempt to incite the public, to convince it (not by orderly arguments but by whipping up radiation phobia) of the perilous consequences of developing nuclear power generation; to present scientists' efforts in this direction in a negative light. If we look carefully at the situation in the energy sector, however, we come to the conclusion that we cannot do without AESs. The world's industrially usable deposits of oil at the current level of consumption will last only about 30-35 years; gas and coal—150-300 years. These are the commonly known data supplied by the International Energy Congress.

Or take another side of the problem—environmental pollution, and the heat effect from burning oil and coal. This is the worst disaster known to any environmentalist—because of the carbon dioxide released during the burning of organic fuels. Specialists believe that it would be madness to replace existing nuclear power stations with coal-fired or some other type.

From all points of view, nuclear power generation is preferable. Uranium deposits are sufficiently large. Nuclear reactor design is continuously being perfected. And, most importantly—with the proper reactor design, responsible utilization, and safe storage of nuclear waste, which is quite realistic, nuclear stations today represent one of the most ecologically clean energy sources.

If we give up on AESs, we will face the necessity of burning all our mineral fuel, then cutting down our forests. There will be no other sources except for them, especially in the North.

This is the dismal prospect awaiting us unless we immediately begin to undertake large-scale construction of nuclear power stations, lift the freeze on construction of hydroelectric stations, and multiply our efforts to create wind power devices.

The desire to create ecologically clean power stations is natural, but the goal is hard to achieve. Meanwhile, the real level of technological progress forces us to study the effects of radiation on biological objects.

In the opinion of Professor Ye. Burlakova of the Physical Chemistry Institute, there are substantial differences in the way radiation affects people. The variations of these differences does not fit at all within the boundaries of the old perceptions. The conclusion that 20-23 percent of observed subjects have very high resistance to radiation provides food for thought. In other words, they can take a doze of radiation that is 100 or more times higher than the maximum allowable level, and after that regenerate quickly and have offspring.

Of course, such knowledge can and should have practical applications. For instance, in selecting people for training for the complex job of operator, who, of course, should not lose his ability to function at the first accidental rise in radiation. Undoubtedly this is a must in forming repair-and-rescue groups, which operate in inherently dangerous conditions. One can safely rely in an emergency situation on people capable of enduring extreme doses of radiation.

The desire to keep reality in perspective inevitably leads to a solution to one more problem. Since the environment cannot be completely rid of pollution—we would have to bring the entire industrial sector to a halt to achieve that—we need to pay more attention to human biology. We should be working on methodologies that could help people increase their body resistance to the impact of a polluted environment. Many specialists believe that the biological potential of a man in resisting many forms of environmental changes, including increased radiation, can be increased.

The "greens" simply have to take the position of common sense. Otherwise they will not be realistically able to help humanity make the world green. While the economy will be forced off the road of progress, creating a precedent of an unheard-of economic crisis on a world scale.

Presidential Ecology Adviser Responds

93WN0251B Moscow ROSSIYSKIYE VESTI in Russian 23 Jan 93 p 5

[Article by Aleksey Yablokov, adviser to the president of the Russian Federation, published under the general heading "The Government's Position: Construction of Nuclear Power Stations Will Continue": "An Ecologist's Opinion: 'Nuclear Scientists Turn Deaf Ear to Alternative Solutions'"]

[Text] The decision to proceed with construction of new nuclear power stations and generating units was made without conducting a state economic [as published] expert evaluation. This violates legislative norms gained with such difficulty in the battle with government agencies after the Chernobyl disaster. The law envisages that "state ecological expert evaluation represents a mandatory measure with respect to protection of the environment, and **precedes** the making of an economic decision." Further on—"financing and commencement of work on all projects and programs is done only if the conclusion of the state ecological expert evaluation is positive." What immediately follows from this is that the decision to order the Ministry of Finance to initiate financing for these projects before conducting an ecological evaluation is unlawful.

Of course, the law also stipulates that building AESs in densely populated areas, resort and rehabilitation zones, and near water reservoirs of republic-level significance is prohibited. If necessity dictates such construction, the decision is made upon holding a referendum.

Thus, the law even prohibits **designing** the stations, the decision on whose construction has already been made. One would think that the minister of environmental protection, Viktor Danilov-Danilyan, would be the first to speak up against adopting this decree. Strangely, however, he concurred. Only Minister of Justice Nikolay Fedorov supported me in that the adopted decree violates the law. Unfortunately, our opinion was disregarded.

I am not saying that I doubt the need to develop nuclear power generation. But the risk undertaken in building AESs must be an acceptable one. The way to go about it is to consider on a competitive basis a number of designs for new safe reactors and only upon conducting a state ecological expert evaluation decide whether they are to be built. Also, why is it necessary to replace capacities going off line by new AESs and nothing else?

Is it not better to use the potential of the VPK [military-industrial complex] conversion? For instance, as some specialists, including myself, propose—using gas turbines. A special commission has been created to deal with such alternative solutions, but it has not met even once yet. We could bring economists and defense specialists into the search for solutions to this problem—people who have told me many times that there are designs that will cost the state two or three times less than building AESs. They had gas turbines in mind. However, those who were given the money "for further development of nuclear power generation" turn a deaf ear to such alternative solutions.

I must also mention the technical violations in the operation of AESs that continue to take place. For instance, on 22 December an incident occurred at the Beloyarsk AES that was rated as a "category one" accident. In the past there was a hidden radiation discharge at the same station. This came through in the results of measurements of radioactive pollution on the territory of Russia conducted from a helicopter in 1991. On the map below you see a spot indicating contamination of an area equal to almost 20 square **kilometers**. The level of radioactive contamination is between 15 and 5^{-3} curies per square kilometer. This data is evidence that a radioactive accident took place resulting in a discharge of enormous concentrations of cesium and cobalt. We did not learn about it until now, though, when a rigorous survey was conducted (the helicopter flew over this spot three times). Thus, the incident at the Beloyarsk AES is already the second one.

Today the Ministry of Atomic Energy won a battle against the ecologists. Over whom is this victory won, however; why do we so seldom look into the future? Now the Ministry of Atomic Energy's hands are untied. The Supreme Soviet Presidium resolution on increasing secrecy in the area of nuclear power generation also "works" for it. From now on all archive documents will be classified for 18 years.

I am convinced, however, that the energy problem can also be solved in other ways. The military-industrial potential that was "eating up" a large share of energy is being substantially reduced. Keep it in mind that 75 percent of enterprises in St. Petersburg alone worked for the VPK.

This means that by cutting the VPK we can substantially moderate the "appetite" for energy. And what about financing for these projects? The implementation of the program's first phase alone will cost at least 20 billion rubles. I am convinced that we can hardly spare this money. Especially considering that economists keep saying persistently that large-scale financial investment should only be made in projects that will have a fast economic effect, and provide a return that will make it possible to improve the life of Russian citizens.

Power Plant 'Incidents' Noted

93WN0251C Moscow ROSSIYSKIYE VESTI in Russian 23 Jan 93 p 5

[Unattributed report: "Accidents at Russian Nuclear Power Stations Between 11 and 18 January 1993"]

[Text] There are currently 28 power generating units operating at nine AESs that are on line in Russia, with a total capacity of more than 20 megawatts. Last week, generating unit No. 4 at the Novovoronezh AES, and generating unit No. 1 at the Kalinin AES (both stations are located in Central Russia) were under repair, as was generating unit No. 2 at the Leningrad AES. Generating unit No. 1 at the Smolensk AES is under capital repair, and generating unit No. 3 at the Kursk AES—under scheduled repair.

The following incidents took place at Russian AESs: On 11 January, due to short circuit a turbogenerator was turned off at generating unit No. 5 at the Novovoronezh AES; the generating unit's capacity was reduced by 50 percent. The turbogenerator was returned on line after a little over an hour.

On 14 January the emergency safety system kicked in at generating unit No. 3 at the Balakovo AES (Volga region). The unit was put on line on 15 January.

On 15 January the output of generating unit No. 1 at the Kalinin AES was reduced to 100 million watts (the station's capacity is 2,000 million watts); the same day, the generating unit was put under capital repairs.

On 16 January a turbogenerator was turned off at generating unit No. 5 of the Novovoronezh AES, due to unsatisfactory repairs to the emergency safety system. The turbogenerator was turned back on the next day.

Physicist: Nuclear Safety Feasible

93WN0251D Moscow ROSSIYSKIYE VESTI in Russian 23 Jan 93 p 5

[Article by Professor Yuriy Ado, chief research associate at the High Energy Physics Institute, Protvino: "A Physicist's Opinion: Nuclear Power Stations Can Be Made Safe!"]

[Text] There are issues in science that willy-nilly affect the interests of everyone and everybody. Such is the AES problem. On one hand, the operation of AESs does indeed involve the risk of an environmentally dangerous situation of varying degrees of gravity. It is understandable that we hear increasingly frequently the opinion that we should abandon building and operating AESs. On the other hand, such an approach to the problem cannot be considered constructive. Given that we have not yet found well-founded options for adequately replacing nuclear stations with some other kind of energy sources, instead of talking about closing AESs we should concentrate on their substantial improvement, which would preclude the causes of accidental nuclear reactor acceleration. There is a known way of doing this.

The main cause of known major AES accidents is that all active AES nuclear reactors operate in a critical mode. A control and safety system failure or an operator error may result (and, alas, do) in the chain reaction of nuclear fissionable fuel becoming uncontrollable, accelerating quickly, and instantly discharging large quantities of heat energy sufficient to cause the explosion of the reactor. There is, however, a method of transferring a nuclear reactor to a near-critical status, in which a chain reaction cannot take place spontaneously. At the same time, the reactor's nominal capacity may be restored by additional irradiation of the reactor's active zone by a powerful neutron flux from an outside source.

The needed intensive neutron flux can be adequately generated by using a proton, heavy water, or other, heavier, charged particle high-current accelerator. Calculations show that, for instance, a proton beam from an accelerator with an energy capacity of about 400 million electron-volts and an average current of about 100 milliampere, "bombarding" a uranium or lead target, can easily produce the required neutron flux. As to building such accelerators, this task is now feasible. It is important to note that the search for the solution to this task is approaching a border area where two problems, two technologies meet—accelerator and reactor technology; as is known from the history of science, such solutions are very productive.

Estimates show that after the AES is equipped with the accelerator device, the cost of the electric power it produces increases by 10-15 percent. This is not too high a price to pay for the ability to practically preclude accidents on a catastrophic scale.

Construction Plan Promises To Revive Nuclear Power Industry

93WN0250B Moscow KOMSOMOLSKAYA PRAVDA in Russian 26 Jan 93 p 3

[Article by O. Volkov: "'Peaceful Atom' Has Snapped Out of It, and Is Mounting an Offensive"]

[Text] It appears that the Russian nuclear power industry has finally recovered from the powerful blow it took in 1986, despite some experts predicting its complete demise, pointing to changes that have shaken the world in recent years: They said that the Soviet population, scared by the accident at the Chernobyl nuclear power station, would not allow the use of nuclear energy to expand.

Indeed, during the entire 6 years since Chernobyl, which have passed under the sign of perestroyka and acceleration, a certain stagnation has been registered in nuclear power generation. They recalled our nuclear specialists only on account of various incidents which, to tell you the truth, were numerous, rather than, as used to be the case, in conjunction with commissioning yet another power unit (incidentally, only four have been commissioned in Russia since 1986).

By now it is already possible to say that the nuclear power industry, which was recently involved in all-around defense, is switching to the offensive, the success of which is largely preordained. This has to do with the fact that, in the 10 years to come, the service life of power units which were built in the early and mid-1980's will come to an end. This will mean additional, very significant difficulties for a country which is already experiencing a power shortage.

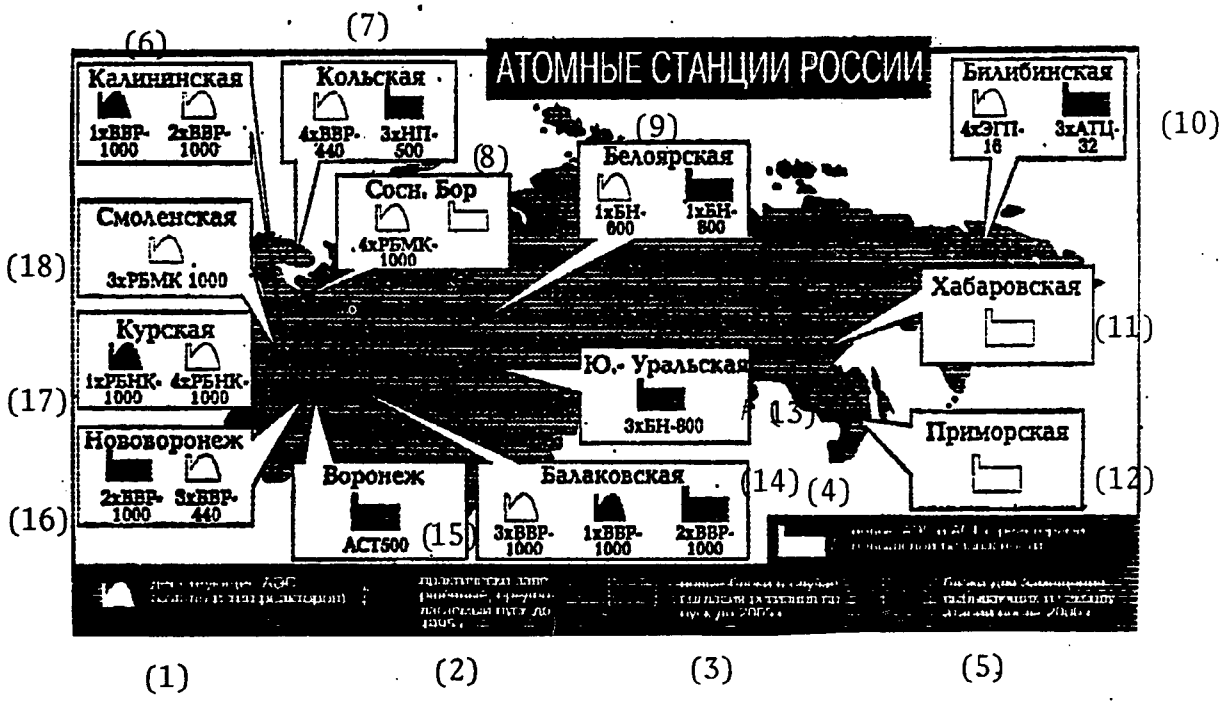
This is why it is not surprising that, on 28 December 1992, the government adopted a special decree, No. 1026, which actually confirmed a program for the construction of new nuclear power stations for generating heat and electric energy until the year 2010. Its initial stage calls for the modernization of operating power units and the commissioning of new ones to replace the units of the Bilibino, Novovoronezh, and Kola nuclear power stations which will be retired after the year 2000. Given the consent of regions and a favorable evaluation by the state ecological review, it would be possible to complete the construction and start up another eight units at the Balakovo, South Urals, and Beloyarsk nuclear power stations and the Voronezh AST [nuclear heating plant]. A technical and economic feasibility study is also being prepared at present for the construction of nuclear power stations and nuclear heating plants of a new generation in regions in which it is often just impossible to generate power in a "nonnuclear" mode: the territories of the Far North and the Far East, the lower Volga area, and the central part of Russia.

However, Unit 3 at the Balakovo nuclear power station, which has successfully passed ecological review, should begin operation as early as April of this year.

Before 1995 it is planned to start up yet another two, almost completed (70 percent), power units—at the Kursk and Kalinin stations. To be sure, at present it is impossible to predict the outcome of a state review of Unit 5 of the Kursk nuclear power station, where a modernized RBMK-1000 reactor with an upgraded safety system, and yet one with a tarnished reputation, is installed.

This is why the program pays considerable attention to the development of new, safer types of reactors—NP-500 and VPBR-600.

The issue of cooperation with the West remains open for now. In the words of Deputy Minister of Nuclear Energy Yevgeniy Reshetnikov, "frequently, the conditions of Western partners are just unacceptable to us." This has to do with the fact that, while foreigners would like to build their nuclear power stations on the territory of Russia, first, "we are capable of doing this just as well ourselves," and second, the "dirty" fuel cycle, with highly active waste and risk, will still remain in our country, whereas the absolutely "pure" electricity will flow to the West. However, this does not mean that Russian nuclear specialists intend to restrict their contacts with foreign colleagues. For example, imported equipment which monitors reactor safety is already installed at some of our stations.



Nuclear Power Stations in Russia

Key: 1. Operating nuclear power stations (number and type of reactors); 2. Virtually complete, expected to be started up before 1995; 3. New units in the event of consent by regions; expected start-up before 2005; 4. New nuclear power stations and nuclear heating plants with improved safety reactors; 5. Units replacing those decommissioned after the year 2000; 6. Kalinin—1 x VVR-1000, 2 x VVR-1000; 7. Kola—4 x VVR-440, 3 x NP-500; 8. Sosnovyy Bor—4 x RBMK-1000; 9. Beloyarsk—1 x BN-600, 1 x BN-600; 10. Bilibino—4 x EGP-16, 3 x ATTs-32; 11. Khabarovsk; 12. Maritime; 13. South Urals—3 x BN-800; 14. Balakovo—3 x VVR-1000, 1 x VVR-1000, 2 x VVR-1000; 15. Voronezh—AST-500; 16. Novovoronezh—2 x VVR-1000, 3 x VVR-440; 17. Kursk—1 x RBNK-1000, 4 x RBNK-1000; 18. Smolensk—3 x RBMK-1000

Chernobyl AES: 15 Years Later

937F0038A Kiev RABOCHAYA GAZETA in Russian
No 24, Sep 92 p 2

[Article by V. Vernodubenko and V. Rassokha, Ukrinform]

[Text] Anniversaries are generally marked and prepared for in some way. It is not easy to speak of an event to whose initial unfeigned joy time has added bitterness and tears, doubts and judgment. We are speaking of the start-up of the No. 1 unit at the Chernobyl AES on 26 September 1977. Today we have tried many times to forget that date. But it is our history, good or bad, and we therefore cannot forget it. Another reason why we decided to take up our pen is because the start-up of the first reactor at the Chernobyl AES marked the beginning of the creation of Ukraine nuclear power generation, which is now at a crossroads.

The road leading to the Chernobyl AES is deserted. Six-plus years ago cement trucks and vehicles loaded with lead and other equipment rushed along it. Toward them came vehicles with people, cattle, and household goods and chattels. It was etched in our memory forever. Through the glass of our special vehicle intended for trips solely in the 30- kilometer zone, we see barbed wire and cemeteries, in one of which Kopachi was recently laid. And then there is the nuclear power plant itself—with the severe boxes of the vessels with their bluish play of colors and, alongside, the destroyed No. 4 reactor in its unique reinforced concrete-and-steel corset. Beyond the channel are the unfinished No. 5 and No. 6 units.

But let us nevertheless return to 15 years ago and listen directly to the event's participants. They are of different ages, and their later fate did not turn out to be easy.

How Did This Happen?

In the frames of the old film chronicle of the unit's start-up one cannot fail to notice the young engineer standing at the turbine panel and intensely following the instruments' readings. And here he is in front of us, sitting gently but still not having lost the lively gleam in his eyes.

"Speaking honestly, I did not think that I would end up on the shift that would start the unit," says Vladimir Berezin, the current head of the multibranch municipal services enterprise of the Chernobyl AES Production Association in Slavuticha. "The feelings are hard to convey. I will just say that the feeling was as for a very much wanted first-born. And it will remain with me for my entire life."

"When the No. 1 unit was erected," Valentin Yezhov, one of many who continue to work at the plant, enters the conversation, "it was cold. We even had to build bonfires in the rooms. But despite all the difficulties, we worked conscientiously from our soul. That is why, in my view, the No. 1 unit turned out to be successful and reliable."

The meeting of the members of the shift that started up the unit, which was then headed by Vladimir Ignatenko, was touching. They are all retired now and living in Kiev. They recalled nearly every minute of that day down to all little details.

In those days Vyacheslav Akinfiyev was the plant's chief engineer.

"The physicists from the nuclear centers in Siberia, Ural, and the Leningrad AES came to our nuclear power plant," he tells. "But the turbine specialists and power engineers were mainly from Ukraine. The team assembled was rather diverse, but they quickly learned how to work well together. If you could have seen how we worked at the Chernobyl AES back then—how strictly we adhered to all the instructions. If it was written that the fuel should be rubbed with alcohol, you could be certain that it was done. And although they had worked the entire day, many stayed for nearly 24 hours. Neither the builders nor the operators went home. They waited to see how the reactor would behave. And the equipment did not let them down. Unfortunately, the technology was not adhered to as strictly when the subsequent blocks were started up. In 1986 the result did not delay in making itself evident."

The Accident Turned Everything Upside Down

We heard the phrase from the plant's directors and its other workers.

"We started up the No. 1 unit merrily," recalls Vladimir Zabolotnykh, chief engineer and radiation chemist. "Indeed we were 15 years younger. A high emotional atmosphere was evident. We knew what we were living and working for. But in one instant both my life and the fate of the 19 members of the shift changed. Five of my comrades got radiation sickness. A pair became invalids, and the dose of irradiation incurred by the others was not small either. And now, after the plant has been closed, even more workers will be cast essentially to the will of fate."

And here it is apt to recall the thought expressed by V. Akinfiyev, who has already been mentioned and who now heads one of the administrations of the Ministry of Chernobyl. Even back then, the physicist-engineers, including Akinfiyev, called the designers' attention to, for example, the significant shortcoming of the type RBMK reactor referred to as a positive reactivity coefficient, which makes it dangerous to operate. But no one in Moscow paid any attention to their comments. And when both the plant and the union Ministry of Medium Machine Building got a new master, i.e., the Ukraine Ministry of Power and Electrification, it became even harder to work because the same thing was heard from Kiev: "Give, give." In other words, the reactor could only be shut down in extreme situations. And even then it was still possible to get a good telling-off.

The nuclear power plant's reactors are now silent. Repairs are under way at the two units that should be

started up this fall. In view of the incident at the Leningrad AES, the cutoff and control valves are being completely replaced. We will share an interesting detail. The plan to replace them (and there are almost 1,700 per reactor) relied completely on Russian enterprises. But there was a stand-by version of the plan as well that involved the Arma production Association. And when the Russian suppliers began ruining the schedule, the Arma came to the rescue. The first batch of valves manufactured by the Kievans turned out to be of a higher quality and half as expensive.

After April 1986 new backup systems protecting against possible accidents were installed at the plant. The Chernobyl AES is the only nuclear power plant in the CIS to initiate an engineering solution that makes it possible to out check the backup diesel-generators while undera load when the plant is working at capacity. The psychology of the nuclear power plant's workers has changed as well. No longer are millions of kilowatts at any price the main thing, but rather the safety and reliable operation of the equipment.

With us today at the plant are American specialists from the radiation protection service of the three nuclear power plants in North and South Carolina. Richard Wilson, senior radiation protection engineer of the company Duke Rauer expressed their opinion: "The safety level at this plant is such that it can be operated on into the future without any special problems."

What Next?

Without a doubt, when the future fate of the Chernobyl AES and ways of developing nuclear power in Ukraine are being discussed, all views and opinions merit careful attention. Some (more than a few) people believe that the Chernobyl AES cannot be safe and that it should therefore be shut down quickly. Others are less categorical. Dmitriy Grodzinskiy, academician of the Ukraine Academy of Sciences and chairman of the National Committee for Protection of the Public Against Radiation, is in favor of shutting down all of the plant's units only after construction of the backup boiler plant has been completed. He supports the idea of continuing economic activity in the 10-kilometer zone.

"No matter what, we will have to deal with this problem in the near future," says Dmitriy Mikhaylovich. "And we must therefore make use of the experience gained in Western countries. In the Nevada deserts in the United States they are deactivating a location where the soil contamination is much deeper than in Chernobyl. The work is calculated to take five years. The soil removed is reprocessed, the radionuclides are separated out, and the pure soil is returned once again. This experience may in some way be useful to the Ukraine. Fast-growing species of trees to produce paper and perennial plants for hay might be cultivated in the zone."

And here is what Nikolay Sorokin, general director of the Chernobyl AES Production Association, thinks about the matter. "I am of the opinion that we must not campaign for nuclear power," says Nikolay Mikhaylovich. "Nevertheless, we must not fail to consider the following. This past winter, Ukraine's nuclear power plants provided up to 40 percent of the electric power consumed. Considering the increase in prices for energy carriers in Russia (and one must think that it will not be the last) and the problems associated with the supply of oil, gas, and coal, Ukraine can hardly get by without nuclear power. As far as our plant is concerned, it is capable of producing 12 billion kilowatt hours of electricity per year or 7 billion rubles' worth. This power is less expensive than that produced by thermal electric power plants. And here is another thing. Let's remember that when the initial decision to halt the operation of the Chernobyl AES was made, it was not ours. All the profits were at the union ministry's disposal. But today the plant is operating as a part of Ukraine's economy. It is truly independent. We are guided by the decisions made by the Supreme Soviet and the government regarding taking the plant out of service in 1993. In my view, however, the documents approved with regard to the Chernobyl AES need, at the minimum, reanalysis in light of the new conditions."

We had the same thoughts expressed by the director of the Chernobyl AES and from Mikhail Umanets, president of the concern Ukratomenergoprom. It is his firm conviction that Ukraine cannot survive economically without nuclear power. The answer lies in the integrated development of power generation, with nuclear power playing a weighty role.

"The statements that the industrially developed countries are phasing out nuclear power plant construction are a myth," noted Mikhail Panteleyevich. "New reactors are today being developed in France, Canada, and the United States. If we do not return to nuclear power generation soon, the gap between us and the West will be even bigger. We are losing specialists in the field in all its links, from science to engineering and technical personnel."

We do not feel that we have the right to give preference to one of these viewpoints or the other. The brief 15-year history of the development of nuclear power generation in Ukraine is too contradictory and ambiguous, the problems that must be solved by the Ukraine government that is now being revived are extraordinarily complex, and the consequences of Chernobyl are grave.

Regulation of Nuclear Sector Inadequate

93WN0250A Moscow ROSSIYSKAYA GAZETA in Russian 13 Jan 93 pp 1-2

[Article by Anatoliy Shramchenko, expert of the Russian Federation Supreme Soviet Committee for Issues of Ecology and Rational Use of Natural Resources and deputy chairman of the Association of Independent Experts on Safety in the Nuclear Power Industry: "The Empire of Nuclear Specialists Does Not Need a 'Nuclear Constitution'"]

[Text] An article by A. Romanov in ROSSIYSKAYA GAZETA (23 October 1992) once again discusses affairs in the nuclear sectors of industry and power generation. Its headline, "Orders Are To Advance—From an Unprepared Bridgehead and in an Unknown Direction," hits the bull's eye.

Indeed, the orders are precisely to advance. There was, and still is, no regular development in our nuclear industries. The government is betting on nuclear power stations with reactors which have already been compromised at the Chernobyl and Leningrad power stations, and whose adequate safety has not been confirmed.

Indeed, there was, and still is, no prepared bridgehead: full-scale testing, model specifications and calculations of reactor safety, an optimized set of measures for protection of personnel and the populace against radiation, and a truly operational safety system. There are other concerns. An energy crisis is exacerbating the economic crisis. The need for power must be met at any price! The safety of reactors and technologies comes next.

Indeed, the offensive proceeds in an unknown direction. There simply is no precise, verified direction, because there is no design of a nuclear power station with an improved safety reactor. They have been working on it unsuccessfully for several years now: After all, they are looking for simple and cheap solutions based on old accomplishments. There is no such direction because the issue of radioactive waste handling is not being resolved: It is drained into temporary storage facilities because there is no industrial technology for solidifying liquid waste; because the creation of regional burial sites for solid waste in safe geological structures is stuck at the stage of technical and economic feasibility studies; because liquid waste containing plutonium is still injected underground at nuclear combines posing a threat of catastrophic radioactive contamination to water-bearing strata, even if remote; because ponds and rivers filled with radioactive water sit out in the open. The direction of the offensive is not known because there are no commonly accepted concepts of safety of nuclear technologies (primarily of nuclear installations) or concepts for ensuring the radiation safety of people and, finally, because there is no system of legislative acts which would regulate the safe use of nuclear energy and govern the types of operations and kinds of relations in which people engage while using nuclear energy.

The authors and inspirers of the government program for the development of nuclear energy cannot be unaware of all this. This is why raising the issue of some kind of offensive in nuclear industries is absurd in itself. All that is possible in this area at present is spontaneous expansion in the interests of a quite narrow circle of individuals—leaders of the nuclear department.

The peculiar state organism, which was first called the Ministry of Medium Machine-Building, subsequently the Ministry of Nuclear Energy and Industry, and now the Russian Federation Ministry of Nuclear Energy, has existed for more than 40 years. For more than 40 years it has operated without a legal foundation. Legislation in the area of the use of nuclear energy and radiation safety began to emerge only after the Chernobyl disaster. However, the rays of legislative regulation in the area of ensuring radiation safety appeared as late as the recently passed laws on the medical and disease-control welfare of the population and the protection of the natural environment. The rest of the laws are still at the draft stage.

In 1986 work on the law on the use of nuclear energy began, which has not been completed to this day. It has been conceived as a directly applicable law, whereby governance and regulation would apply only to what the leadership of the nuclear industries sanctions. The draft was submitted for consideration to the Supreme Soviet of Russia as late as the fall of 1992.

In 1991 and 1992 a law on policy in the area of handling radioactive waste was developed. This is also a directly applicable law, which, in the interests of nuclear departments, envisages the creation of yet another independent nuclear department specifically for handling wastes. The draft was also transferred to the Supreme Soviet in the fall of 1992.

In 1992 a law on the radiation safety of the populace was urgently prepared. It is also a directly applicable act. However, in terms of its approach to regulation and governance on safety issues, it clearly contrasts with the above two laws because it reflects the interests of an independent department for medical and disease control supervision rather than those of nuclear specialists. The future of this law is very much in doubt.

In 1992 the development of two laws for the area of the defense uses of nuclear energy began; the laws reflect solely the interests of the defense industries to a considerable degree.

Finally, in November 1992, the draft law of the Russian Federation "On the Status of Territories Polluted as a Result of Chernobyl or Other Radiation Accidents or Those Exposed to the Risk of Radioactive Contamination" was published. It was prepared by the Committee for Ecology and Rational Use of Natural Resources. It is oversaturated with theoretical provisions from medical radiology and radiation hygiene and generalities about the safety of nuclear stations. This directly applicable law resembles a collection of quotes from scientific publications. It does reflect someone's specific interests, but it does not codify the status quo or establish the legal regime of territories which have been, or may be, affected by radioactive contamination.

As we can see, the familiar merry-go-round of spontaneous expansion is beginning to spin in the area of laying a legislative foundation as well. However, a system of legislative acts should be built organically, on the basis of commonly accepted concepts, in all areas of legislation,

with the coordinated sequence of the development of individual laws taking into account their conceptually justified hierarchy.

This is where we come to the focal thesis, as we see it, which A. Romanov has repeatedly voiced on the pages of central newspapers. It is the thesis about the "nuclear constitution." What does this mean? It means the Russian Federation Law "On Fundamentals of Legislation in the Area of the Safe Use of Nuclear Energy and Sources of Ionizing Radiation." This law should legally codify the entire system of objects, subjects, and types of operations and relationships in the sphere in question. It should set forth the main principles of safety, its criteria, and norms. It should also include fundamental banning rules resulting from domestic and world experience. This law should codify the main terms and notions, determine the hierarchy of legislatively regulated safety requirements, and on this basis, establish a hierarchy of directly applicable laws and the main executive acts. This law should delimit the entire legal scope of the nuclear sphere. If this law comes along, the directly applicable laws will no longer duplicate one another; contradictions between them will disappear; it will be clear which areas of the legal space are not yet covered by legislation.

However, this suits the empire of nuclear specialists least of all. This will mean the beginning of the end of this empire. If the law specifies subjects of nuclear law, every person will be able to influence the state of affairs in nuclear departments. Public organizations will be able to subject them to the procedure of public investigation (hearings). It will not be possible to ban rallies and demonstrations in the sanitary protective zones of nuclear power stations, as does the draft law on the use of nuclear energy.

In general, this is a "strange" draft. It does not include a definition of radiation safety. It does not say that it is mandatory to use commonly recognized international norms and recommendations of the IAEA [International Atomic Energy Agency] in our norms. Responsibilities and guarantees pertaining to the organs of state regulation, supervision, and monitoring of the safe use of nuclear energy are not determined unambiguously.

These are not mere shortcomings or defects. These are expressions of the imperial ideology of nuclear specialists. If only this were the case solely with draft laws! For example, an outline of safety guarantees ensured by the State Committee for Monitoring of Nuclear and Radiation Safety is completely absent in the texts of "Regulations on the State Committee under the Russian Federation President for Monitoring of Nuclear and Radiation Safety" and the "Policy Statement" of this committee. Likewise, it is not defined what the committee is responsible for. This is no accident. After all, all these drafts, regulations, and statements are written by like-minded people, and frequently by the same people.

The draft law on the use of nuclear energy does not contain provisions for a ban on the enactment of all kinds of temporary or special rules or norms which are crucial to our nuclear practices, despite the fact that such rules and norms have been the root cause of almost all of our radiation accidents at transportation and space reactors. They have also caused additional difficulties in providing radiation protection for the population in the accident zone around the Chernobyl Nuclear Power Station. The draft omits all facilities with technologically modified radiation backgrounds. This would have placed within the scope of legislative regulation the "holy of holies" of the empire of nuclear specialists—the radiation and ecological consequences of the mining and processing of uranium and polymetallic ores.

I believe that the time has finally come to invite the attention of the deputies to the actual state of affairs in nuclear departments.

Luminescent Procedure for Monitoring Serviceability of Solar Modules and Batteries Based on AlGaAs Photocells With Radiation Concentrators

937F0109A Tashkent GELIOTEKHNIKA in Russian
No 5, Sep-Oct 92 pp 3-7

[Article by V.D. Rumyantsev, M.Z. Shvarts, Engineering Physics Institute imeni A.F. Ioffe at Russia's Academy of Sciences; UDC 621.382]

[Abstract] The difficulty of ensuring the required spectral radiation composition, density, power, and stability in solar module and battery simulators used for checking the serviceability of actual devices, especially in prelaunch tests of space vehicle batteries, prompted the development of a new technique based on the use of luminescent semiconductor materials which encompasses both the photoelectric and geometrical parameters. Photocells (FE) with a *p-n* junction in a luminescent material are used for this purpose, e.g., AlGaAs structures. The procedure of checking the solar concentrator modules and batteries amounts to analyzing the near field of the electroluminescent (EL) radiation generated in the photocells under forward current and emerging from the concentrator panel. The electroluminescence pattern is observed at a distance whereby the angular dimensions of each concentrator are several times smaller than the sun's angular dimensions. A sixteen-cell concentrator is used in the study. The proposed technique makes it possible to identify defective photocells, groups of cells, and whole modules and eliminate the defect causes, i.e., a degradation of their electric characteristics or misalignment. The authors are grateful to V.M. Andreyev for support and to V.R. Larionov and K.Ya. Rasulov for providing photocell samples. Figures 3; references 5.

Silicon Solar Cells With Ta_2O_5 Antireflection Coating

937F0109B Tashkent GELIOTEKHNIKA in Russian
No 5, Sep-Oct 92 pp 11-13

[Article by G.B. Abdullayev, M.Ya. Bakirov, N.A. Safarov, Physics Institute at the Azerbaijani Academy of Sciences; UDC 621.362:621.383.5]

[Abstract] The advantages of antireflection coatings for increasing the effectiveness of solar cells (SE) which lower the reflection of the incident light in the spectral response area due to the interference effect are noted and it is shown that the solar cell performance can be improved even further by using Ta_2O_5 antireflection coatings instead of the traditional silicon dioxide films. The photoelectric characteristics of Si solar cells coated with a Ta_2O_5-based antireflection film are investigated. To this end, samples are made by diffusing onto *p*-Si with a 4×10^{15} cm^{-3} initial concentration while the Ta_2O_5 antireflection coating is applied by thermolysis. The load voltage-current characteristics of the solar cell before and after applying the Ta_2O_5 coat, the spectral response of the cells before and after the coat application, and the cell reflectance before and after the antireflection coating application are plotted. The study demonstrates that application of a coating with an optimum thickness increases the solar cells' efficiency (KPD) by 35% due to a decrease in their reflectance. Figures 3; references 4.

Solar Heat Supply System With Increased Efficiency

937F0109C Tashkent GELIOTEKHNIKA in Russian
No 5, Sep-Oct 92 pp 59-62

[Article by M.M. Polunin, V.D. Petrash, Odessa Civil Engineering Institute; UDC 662.997:621.472]

[Abstract] The shortcomings of existing solar heat supply systems which are incapable of using the solar energy during the times when the heat demand is low but the solar radiation flux is sufficient and the need for additional water heaters and accumulators prompted the development of a new system which is free of the aforementioned flaws. The design and operating principle of the new system are outlined in detail. Cold tap water (KhV) is heated in a solar heater (VPG) and enters the hot water supply system (SGV) directly if its temperature corresponds to a certain standard level. Excess water is pumped to the upper zone of the storage tank (BA). The proposed design not only ensures the optimum temperature head of 2-5° C but also heats up the heating system's heat transfer agent. The system also makes it possible to extend the sunlight utilization period, use the surge tank as a heat accumulator, and use the heating system as a water reheater. The proposed system is characterized by an elevated functional reliability and ability to use effectively solar energy even at a low heat flux density. A certain complication of the equipment necessary for implementing the design is paid off by fuel savings. The system is recommended for incorporation in building practices. Figures 1; tables 1; references 4.

Numerical Systems Analysis of Solar Collector

937F0109D Tashkent GELIOTEKHNIKA in Russian
No 5, Sep-Oct 92 pp 28-32

[Article by V.V. Moiseyenko, Yu.L. Myshko, S.V. Smirnov, Scientific Research Institute of Occupational Safety Equipment for Building and Structures, Kiev; UDC 662.997]

[Abstract] A new Pascal routine developed for designing a solar collector for commercial implementation is described; the program is intended for analyzing existing and developing prospective collector models by exhausting all possible design versions. In so doing, the structure efficiency, cost, and mass are used as the comparison criteria whereby each version is characterized by a set of manipulated variables. In order to debug the solar collector systems analysis program and order

the set of manipulated variables, a numerical study is carried out. To this end, the manipulated variables are separated into three groups: dimensional or geometrical quantities, thermal quantities which characterize the properties of materials or are attained as a result of the process, and the parameters determined by the system, e.g., the absorber surface temperature, internal channel heart transfer coefficient, collector slope to the horizontal surface, and the angle of incidence. As a result, solar collector design becomes a multicriterial task according to the goals and a multifactor task according to the parameters under study; the solar collector efficiency is actually determined by sixteen parameters. Figures 1; tables 1; references 3.

Dynamics of Optical and Mechanical Characteristics of New Greenhouse PVC Films

937F0109E Tashkent GELIOTEKHNIKA in Russian No 5, Sep-Oct 92 pp 63-67

[Article by I.Ye. Markov, All-Russian Scientific Research and Design Institute of Rural Industrial Development, Orel; UDC 662.997:537.22]

[Abstract] The influence of the optical and mechanical properties of translucent films on the greenhouse film efficiency and the shortcomings of existing SK and ST polyethylene (OE) films, e.g., their high optical radiation permeability in the infrared (0.7-20 μm) spectrum (IKR) leading to high heat losses at night are discussed. A new pilot batch of polyvinyl chloride (PCKh) films manufactured at the Kaprolaktam Production Association is tested and the results of the optical and mechanical tests are presented. The dynamics of elongation of pilot 0.24 mm PVC films, the outcome of lab tests of the films, the direct flux transmittance of the new PVC films, the dynamics of integral transmittance of 0.24 mm films tested in light zone III, and the dynamics of integral transmittance of 0.24 mm films in light zone VI are summarized. As a result, recommendations are made for using films with various thicknesses in different sun light zones. The economic impact from the use of new PVC films due to an increase in their weather resistance and an increase in the crop yield in the greenhouse is 0.98 rub/m^2. Tables 5; references 14: 13 Russian, 1 Western.

Possible Effect of the Influence of Ultrasound on the Critical Temperature of High-Temperature Superconduction

937F0108B Tashkent DOKLADY AKADEMII NAUK RESPUBLIKI UZBEKISTAN in Russian No 2, Feb 92 (manuscript received 6 Nov 91) pp 22-24

[Article by B.L. Oksengendler, Yu.V. Pakharukov, and P.K. Khabibullayev, corresponding member, USSR Academy of Sciences, Thermal Physics Department, Republic of Uzbekistan Academy of Sciences; UDC 538.945]

[Abstract] The possible effects of ultrasound on the critical temperature of high-temperature superconduction has been examined mathematically on two levels, i.e., at the level of the elementary cell and on scales comparable with the dimensions of microcrystallites. At the microscopic level, ultrasound can affect the critical temperature of high-temperature superconduction by causing a redistribution of the oxygen atoms with respect to the O_4 and O_5 positions in the given superconductive material. The extent of this change will in turn depend on the intensity and frequency of the sound. Comparing the theoretical dependences presented herein with experimentally derived dependences will make it possible to obtain the respective microparameters of given materials. Mesoscopic effects, on the other hand, are most fully apparent in ceramic materials containing a large number of interfaces between crystallites. These boundaries generally contain a surplus of O that in turn determines the potential relief of the two boundaries of the crystallites. It is significant that in regions with reduced stoichiometry, the depth of the wells is lower. Under the effect of ultrasound, the region between the crystals is compressed, thus intensifying the Coulomb repulsion of the O ions. Subjecting such a material to ultrasound will cause oxygen to move out of the sinks of the intercrystallite space, thus homogenizing the given material with respect to O. This should in turn result in a decrease in ΔT_c on the experimental curve $\rho(T)$ (the width of the superconductive transition) with a simultaneous increase in T. This effect should be most evident at the base of the curve $\rho(T)$. Figure 1; reference 1 (Western).

An Experimental Study of the High-Speed Entry of an Elastic Cylinder Into Water

937F0088A Moscow IZVESTIYA ROSSIYSKOY AKADEMII NAUK MEKHANIKA ZHIDKOSTI I GAZA in Russian No 5, Sep-Oct 92 (manuscript received 20 Dec 91) pp 20-30

[Article by V.A. Yeroshin, Moscow; UDC 532.5.013.2:539.3]

[Abstract] An experimental study examined the penetration of an absolutely solid disk (a cylinder on its end) into liquid at an angle to the free surface. The primary objective of the study was to gain a comprehensive understanding of the various aspects of the processes occurring during penetration and on their interconnection. Immersion was examined from the moment when the disk made its initial contact with the liquid surface to the point where its motion became quasi-stationary. The first part of the study was devoted to determining the impact loads involved in the process. Expressions were derived for determining the hydrodynamic forces involved and their moment over a broad range of Mach numbers and entry and attack angles. The experimental data confirmed the existence of hydrodynamic similarity during the asymmetrical immersion of an absolutely solid disk into a compressible liquid with one exception. The moment of the hydrodynamic forces at work was found to be a very sensitive indicator of pressure distribution that could register a deviation from the linear theory that is difficult to grasp by the method of direct measurement of pressure. Published numerical calculations of pressure on the surface of an absolutely solid disk upon asymmetrical entry into water at speeds up to 1,500 m/s were found to be in satisfactory agreement with the results of the physical modeling. The changes in the solid disk's stress-strained state as a result of the complex wave system excited in the immersed body by shock loads were also examined. Problems of hydrodynamics and the dynamic theory of elasticity were solved simultaneously in an effort to describe these wave processes adequately. The contents of the wave packet propagated throughout the cylinder was found to depend on the disk's entry angle. Longitudinal waves were excited upon vertical symmetrical penetration, whereas flexural waves were excited at low entry angles. The disk's motion in the initial stage of immersion was also examined with special attention to both angular velocity and stability of motion. At low entry angles, the angular velocity was found to have a characteristic feature of the form $1/\theta_0$. Both calculations and experiments confirmed the oscillatory nature of the cylinder's motion in the underwater portion of its trajectory and the increase in the oscillations's amplitude. Figures 8; references 23: 21 Russian, 2 Western.

The Impact of a Rectangular Plate Against a Fluid Half-Space

937F0088B Moscow IZVESTIYA ROSSIYSKOY AKADEMII NAUK MEKHANIKA ZHIDKOSTI I GAZA in Russian No 5, Sep-Oct 92 (manuscript received 7 Dec 90) pp 120-126

[Article by N.A. Veklich, Moscow; UDC 532.582.2]

[Abstract] A theoretical study examined the potential flow of an ideal incompressible liquid filling a half-space when subjected to the impact of a rectangular plate along its surface. It is assumed that upon impact, the plate transfers a specified velocity to the liquid particles on the surface of the half-space. Outside the plate, the surface of the liquid is free, and the impulsive pressure on it equals 0. An integral equation of the first type is derived for the impulsive pressure under a flexible plate. The equation is then solved on a computer by the power series methods

for the particular case of the impact of a rigid nondeformable plate. Theoretical dependences of the coefficients of the apparent additional mass and apparent additional inertial moments of the nondeformable plate on the plate's geometry are plotted and compared with experimental data and published empirical formulas that are not directly related to the solution of a Laplace equation. The approximate solutions obtained for the dependence of the coefficient of apparent additional mass on the plate's geometry showed good consistency with experimental results in cases of long plates. In cases of plates that are not very long, the calculated values of the coefficient λ are noticeably higher than the experimental data, with the greatest discrepancies (by more than 8.6%) occurring with square plates. Only a few of the calculated values of the dependence of apparent additional inertial moment on plate geometry were consistent with experimentally obtained values. Calculations of the same dependences based on methods of integral sums and collocations proved to be inferior to calculations based on the power series method from both convergence and reliability standpoints. The power series method proposed was also said to be applicable in studying the dynamic interaction of rectangular elastic plates with an ideal incompressible liquid. Figures 3; references 4: 2 Russian, 2 Western.

The Three-Dimensional Circulation of Wings by a Hypersonic Gas Flow

937F0088C Moscow IZVESTIYA ROSSIYSKOY AKADEMII NAUK MEKHANIKA ZHIDKOSTI I GAZA in Russian No 5, Sep-Oct 92 (manuscript received 6 Feb 92) pp 148-161

[Article by V.N. Golubkin, Moscow; UDC 533.6.011.5]

[Abstract] The three-dimensional circulation of wings by a hypersonic flow under an attack angle is characterized by the formation of a compressed shock layer of gas close to its windward surface and by intensive rarefaction with negligible pressure on its leeward side. Despite that fact that the windward flows are very complex and generally contain separation zones whose connecting points are sites of heat flux peaks, the windward shock layer plays the main role in the formation of aerodynamic forces and heat transfer to the surface of the bearing wing. A number of phenomena specific to hypersonic flight complicate the study of current in a shock layer. First, there is the intensive eddy formation that results from the strong and uneven increase in entropy and that plays the decisive role in the formation of the current's structure. Next, there is the fact that the currents behind the intensive compression shocks are very irregular and contain sharp vorticity, pressure, and entropy gradients. These irregularities and gradients necessitate the isolation and asymptotic consideration of a number of subregions, such as singular sections and entropy and vortex layers, whose interaction with the viscous boundary layer has a marked effect on heat transfer. In addition, in cases of high flight speeds and altitudes, the air in the impact layer can no longer be considered an ideal gas, and its real properties must be taken into consideration. Because the shock layer in cases of three-dimensional circulation of a wing by a hypersonic gas flow is highly compressed as a result of intensive physicochemical reactions (primarily the dissociation of molecules at high temperatures) resulting in a decrease in the effective adiabatic exponent, the concept of a thin shock layer as a limit corresponding to the striving of the adiabatic index κ to unity (1) has proved to be extremely productive both in constructing a rather complete theory of circulation and in calculations with a precision adequate for practical use. This approach has made it possible to use approximate formulations of the problem of three-dimensional circulation by a hypersonic gas flow to derive similarity laws and analytical and numericoanalytical solutions that in turn yield explicit, albeit sometimes complex connections between aerodynamic characteristics and diagnostic variables. The results obtained in this manner may then be used for preliminary estimates and calculations so as to avoid the substantial problems and expenditures of computer time and resources that are required for exact numerical calculations of three-dimensional currents. The said results may also serve as a foundation for formulating and solving variational problems of selecting optimal forms of bearing surfaces for hypersonic velocities. Navier-Stokes and hypersonic turbulent boundary layer equations have also been used for a number of years to study the hypersonic circulation of bodies by viscous gas. Analytical solutions of problems of nonviscous circulation are also used as external solutions in the construction of rational asymptotic theories of viscous and detached flows. Figures 7; references 35: 32 Russian, 3 Western.

The Compression of Gas During Interaction With a Stationary Axisymmetric Converging Shock Wave With a Quasi-Conical Point

937F0088D Moscow IZVESTIYA ROSSIYSKOY AKADEMII NAUK MEKHANIKA ZHIDKOSTI I GAZA in Russian No 5, Sep-Oct 92 (manuscript received 10 May 89) pp 162-167

[Article by I.V. Sokolov, Moscow; UDC 533.6.011.72]

[Abstract] A theoretical study was conducted to examine the gas compression occurring upon the interaction of a stationary axisymmetric converging shock wave with a quasi-cone (a body shaped approximately like a blunted cone). The primary objective of this study was to determine the density beyond the reflected wave and the pressure on the cone. A "quasi-cone" was studied instead of an actual cone to simplify the calculations required. A piston analogy was used as a basis for formulating a self-similar problem, and the self-similar equation system was integrated. The self-similar solution and use of a piston analogy made it possible to find the density at the front of the reflected wave. The main result of the study was that it proved the possibility of creating high values of compression of the medium in a special type of flow. The values obtained were comparable to those compressions that can be obtained by

using spherical shock waves (converging and reflected). Figures 3; references 10: 9 Russian, 1 Western.

The Interaction of a Shock Front With a Waveform Contact Discontinuity

937F0088E Moscow IZVESTIYA ROSSIYSKOY AKADEMII NAUK MEKHANIKA ZHIDKOSTI I GAZA in Russian No 5, Sep-Oct 92 (manuscript received 25 Jun 91) pp 168-174

[Article by A.N. Aleshin, V.V. Demchenko, S.G. Zaytsev, and Ye.V. Lazareva, Moscow; UDC 533.6.011.72]

[Abstract] The passage of a shock wave through a waveform contact discontinuity separating gases of different density results in an increase in the discontinuity's amplitude. This increase in amplitude in a certain stage is in turn accompanied by the formation of vortex structures and culminates in the formation of a turbulent region of mixing that separates the flows of the starting gases. This phenomenon is termed a Richtmayer-Meshkov instability. The excitation of Richtmayer-Meshkov instabilities may be observed when high energy densities are produced, such as when laser-irradiated targets are compressed. The excitation of a Richtmayer-Meshkov stability for cases where $a_0k > 1$ (where a_0 is the amplitude of the initial contact discontinuity and $k = 2\pi/\lambda$ [λ being the wavelength of the initial contact discontinuity]) was examined both numerically and experimentally. The experimental study was performed in a shock tube whose low-pressure chamber had a channel section of 7.2 x 7.2 cm^2. the chamber was divided into two parts by a thin Lavsan film (2 μm thick) and was filled with gases (argon and xenon) having a strictly identical pressure. The Toepler method was used to record the process. The Mach number of the starting shock wave was varied from 2.5 to 3.5, and the initial pressure of the gases was 0.5 atm. The Atwood number $A = (\rho_2 - \rho_1)/(\rho_2 + \rho_1)$ was varied from 0.2 to 0.92. A model of an ideal multicomponent compressible medium with $\gamma = 5/3$ described by a system of two-dimensional Euler equations was used. A divergent two-dimensional version of the net-characteristic method was used to obtain a numerical solution of the problem formulated. The difference net covering the calculation region was a fixed Euler net with 520 cells with respect to the x coordinate and 36 cells with respect to the y coordinate. A contact discontinuity K was created between the two high-temperature flows when the film simulating the starting contact discontinuity K_0 was destroyed by an incident shock wave. As a result of the film's destruction due to the mechanical action of the pressure at the shock wave front and the subsequent heat effect of the surrounding flow on the individual fragments, a layer with a final thickness of 2 to 3 mm formed. This layer consisted of the products of the disintegration of the film and the contacting gases. The shape of the contact regions formed was found to correspond to the shape of the film. With a precision to its thickness, this layer may be considered a contact discontinuity surface. The film formed was two-dimensional in the plane perpendicular to the sounding light beam propagated along the z axis. Increasing the curvature of the starting contact discontinuity was found to intensify the evolution of the contact discontinuity (i.e., the development of the Richtmayer-Meshkov instability). As the curvature was increased, the time required for formation of the high-pressure maximum t_1 and t_2 decreased, and the amplitude increased. As a result, the time of transition to the turbulent stage decreased as well. The rate of change in the length of the mixing region in the culminating turbulent stage did not appear (within the bounds of the measurement error) to depend on the initial conditions of the interaction or on the values of λ and A. Figures 5; references 6: 4 Russian, 2 Western.

Supersonic Circulation of Regions of Energy Release

937F0088F Moscow IZVESTIYA ROSSIYSKOY AKADEMII NAUK MEKHANIKA ZHIDKOSTI I GAZA in Russian No 5, Sep-Oct 92 (manuscript received 29 May 91) pp 179-182

[Article by L.V. Terentyeva, Moscow; UDC 533.6.011.5]

[Abstract] The problem of the supersonic circulation of three-dimensional axisymmetric regions of heat release has been solved within the framework of a linear theory. The dependence of the distribution of parameters along the flow on the shape of the region of heat release was studied. Sources of energy release were assumed to be distributed three-dimensionally in a flow of ideal gas. No boundary conditions were imposed on the surface bounding the heat release region; in other words, the gas could flow through the regions. Only supersonic flows were considered; the flow in the undisturbed region was assumed to be homogeneous. The heat inflow was assumed to be small, and the flow was assumed to be nearly uniform. It was assumed that the heat release occurs evenly in a finite space having the form of a round cylinder (with a length of L and a radius of R). When $L < kR$, the solution is somewhat different from that when $L > kR$: The distributions of pressure disturbances along the x-axis in the two cases differ; however, the minimum pressure disturbance is reached at the very same point. In all cases of supersonic circulation of cylindrical regions of heat release, elongated low-pressure zones are formed beyond the said regions. The dimension in this zone are such that it can hold a body that will possess less resistance than in the case of the absence of any heat inflow. Figures 2; references 10 (Russian).

The Hypersonic Circulation of Narrow-Delta Wafers at Large Attack Angles

937F0088G Moscow IZVESTIYA ROSSIYSKOY AKADEMII NAUK MEKHANIKA ZHIDKOSTI I GAZA in Russian No 5, Sep-Oct 92 (manuscript received 4 May 90) pp 183-185

[Article by N.S. Bachmanova, V.I. Lapygin, and Yu.M. Lipnitskiy, Moscow; UDC 533.6.011.55]

[Abstract] A numerical algorithm based on the establishment of a conical solution over time was used to solve the problem of the hypersonic circulation of a plane triangular wafer with large sweep angles χ at attack angles α close to $\pi/2$. The existence of a conical flow when α is approximately equal to $\pi/2$ whose velocity vector is directed to the wafer's tip was considered. The values of $C_p/\sin^2\alpha$ (C_p being the pressure coefficient) and the thickness of the shock layer in the wafer's symmetry plane as a function of the parameter of hypersonic similarity $k = \text{tg}\alpha\text{tg}\chi$ were determined. The calculated results were found to be in good agreement with experimentally obtained data. The thickness of the shock layer was found to be most significant in the symmetry plane. It decreased monotonically as the leading edge was approached. As the angle of attack increased, the Mach number on the wafer's symmetry axis became equal to 1 ($\alpha = \alpha_1$) and then 0 ($\alpha = \alpha_2$). When $\alpha > \alpha_2$, the velocity vector of the flow in the shock layer was directed to the wing's tip. The circulation modes found were qualitatively analogous to those of round cones, and the values of α_1 and α_2 were weakly dependent on χ and M_∞. For the flow modes considered, the spread line is the symmetry axis. The study thus established that just as in the case of round cones, there is a conical flow mode on the windward side of an infinite triangular wafer during which the flow's velocity vector is directed toward its tip. In the case of a triangular wafer of finite length, the conical flow is evidently destroyed when $\alpha > \alpha_2$. Figures 3; references 7 (Russian).

Effect of the Formation of Excited Oxygen Molecules on the Kinetics of Exchange Reactions and Magnitude of Heat Flux During Braking in the Upper Layers of the Atmosphere

937F0088H Moscow IZVESTIYA ROSSIYSKOY AKADEMII NAUK MEKHANIKA ZHIDKOSTI I GAZA in Russian No 5, Sep-Oct 92 (manuscript received 25 Mar 91) pp 186-188

[Article by V.D. Berkut, Dnepropetrovsk; UDC 533.6.011.8]

[Abstract] A theoretical study examined the effect of the formation of excited metastable oxygen molecules on the heat flux occurring under characteristics conditions of the entry of a blunted body into the upper layers of the atmosphere along a gliding trajectory corresponding to the maximum heat load. The magnitude of the heat flux to the body was determined by finding the numerical solution of equations of a thin viscous shock layer at the critical point of a sphere circulated by a supersonic air flow. A finite-difference scheme of fourth-order approximation was used. The increment of the net was reduced in the shock layer and close to the surface. In the calculations it was assumed that Pr = 0.7 and Sc = 0.5. Consideration was given to the effect of the metastable oxygen molecules on the kinetics of gas-phase reactions; the occurrence of reverse reactions; reactions of the dissociation of molecules of oxygen, nitrogen, and nitrogen oxide; and reactions of the recombination of oxygen and nitrogen reactions. Published reaction rate constants were used. The numerical calculations performed demonstrated that given the study conditions, reactions of gas-phase recombination and reactions involving metastable oxygen molecules may be ignored. Heterogeneous reactions were considered for silicon dioxide, which is the basis of the low-catalysis materials used for the heat shielding of returnable spacecraft. The calculations were performed for an oncoming flow speed of 6.7 km/s, a density of 0.8×10^{-4} kg/m^3, a body nose radius of 0.75 m, and a surface temperature of 1,900 K. The calculations established that when $K_{wN} = K_{wO}$, the effect of the formation of metastable oxygen molecules on the magnitude of heat flux is negligible. When $K_{wN} = 0.3K_{wO}$, the effect that the formation of metastable oxygen molecules on the body's surface has on the magnitude of heat flux increases significantly. The decrease in heat flux amounts to 12% in one case examined and up to 20% in another. The observed increase in the role of excited metastable oxygen molecules was attributed to the decrease in the rate of occurrence of the exchange cycle of the reaction as a result of the decrease in the concentration of oxygen molecules in a ground electron state. The maximum decrease in heat flux was in the range of values $\zeta_{wO} = 0.2$ to 0.5. The experimentally measured value of K_{wO} at a surface temperature of 1,900 K amounts to 10 m/s, which corresponds to $\zeta_{wO} = 0.3$. Figures 2; references 7: 5 Russian, 2 Western.

Controllability and Regulation of Program Movements of Reversible Mechanical and Electromechanical Systems

937F0104A Moscow PRIKLADNAYA MATEMATIKA I MEKHANIKA in Russian Vol 56 No 6, Nov-Dec 92 pp 968-975

[Article by Yu.K. Zotov, A.V. Timofeyev, St. Petersburg; UDC 531.36; 62-50]

[Abstract] The issue of controllability and methods of regulating the stored-program movements of a broad range of mechanical and electromechanical systems (MS and EMS) with reversible control are considered and the dynamics of these systems are described by differential equations; regulatability is defined as the existence of a control law with a state vector feedback. The controllability and regulatability conditions of nonlinear mechanical and electromechanical systems are investigated and algorithms are synthesized for constructing programmed movements and their stabilization. The proposed solution methods are based on the property of reversibility of mechanical and electromechanical dynamic systems of equations relative to their control. The reversibility of the dynamic equations and transformation of the coordinates to a canonical form are considered in detail. The resulting synthesized control laws ensure an asymptotic stability of programmed movements as a whole for the nonlinear reversible controllable systems (OUS) with

estimates of the transient processes (PP). For illustration, control of actuating mechanisms and direct current motors (DPT) is examined for MS and EMS systems, respectively. References 13.

Inverse Problem of Unguided Missile Dispersion

937F0104B Moscow PRIKLADNAYA MATEMATIKA I MEKHANIKA in Russian Vol 56 No 6, Nov-Dec 92 pp 985-992

[Article by B.I. Konosevich, S.S. Savchenko, Donetsk; UDC 531.567]

[Abstract] The problem of determining the characteristics of initial, design, and wind-generated perturbations from known scattering characteristics of the slowly rotating unguided missile (RS) point of impact is considered in the deterministic and probabilistic formulation. After leaving the launcher, the missile is regarded as a nondeformable solid containing a solid propellant charge moving in a uniform gravitational force field in a constant horizontal wind under the effect of the jet propulsion force, reactive Coriolis force, and aerodynamic force and the corresponding momenta. The undisturbed missile and the disturbed motion of the disturbed missile, perturbations of the point of impact coordinates, a primal deterministic scattering problem (PDZR), the inverse deterministic scattering problem (ODZR) formulation, the properties of solutions and computation methods, the primal probabilistic scattering problem (PVZR), and the inverse probabilistic scattering problem (OVZR) are considered in detail. The analytical methods developed for solving the above problems and the computer-aided linearization and statistical testing methods are discussed. For illustration, the solution of the inverse problem for the RS-2 missile which differs from the RS-1 missile only by the stabilizer fin design is considered. Figures 1; tables 1; references 3.

On Global Stability of Steady-State Solid Rotations

937F0104C Moscow PRIKLADNAYA MATEMATIKA I MEKHANIKA in Russian Vol 56 No 6, Nov-Dec 92 pp 993-997

[Article by G.A. Leonov, A.V. Morozov, St. Petersburg; UDC 531.383:521.2]

[Abstract] Euler's dynamic equations which describe the movement of an asymmetric solid around the center of mass in the field of constant external and dissipative momenta are considered assuming that the external momentum defined in a body axes system of coordinates is applied along the median principal central axis of inertia. An attempt is made to identify areas in the space of parameters for which the set of steady-state rotations of the body is stable under any perturbation of the instantaneous angular velocity vector. The study is carried out on the basis of Lyapunov's direct method using the elements of the qualitative theory of multidimensional dynamical systems. The stability of steady-state solid movements as a whole is considered and the global stability of stationary movements is analyzed in detail. The global asymptotic stability conditions are established. References 14.

Local Boundedness of Perturbed Imperfect Gyro Movements in Gimbal Mounts With Dissipative and Accelerating Forces

937F0104D Moscow PRIKLADNAYA MATEMATIKA I MEKHANIKA in Russian Vol 56 No 6, Nov-Dec 92 pp 998-1005

[Article by S.A. Belikov, St. Petersburg; UDC 531.383]

[Abstract] A heavy unbalanced dynamically symmetric gyro with structural imperfections in gimbal suspensions is considered in a central Newtonian field of forces. The gyro frame's shaft is fixed on a stationary base and the inner frame (housing) shaft is fixed in the body. The imperfect gyro's equations of motion with dissipative and accelerating forces and their partial solution are considered and a reduced system of equations with two degrees of freedom is derived accurate to third-order terms. The equations of perturbed motion of the reduced system, the characteristic equation and assumptions about the eigenvalue properties, and normalization of the perturbed motion equation and sufficient conditions of local boundedness are examined in detail. The local boundedness conditions are interpreted in a particular case where all parameters except for two are fixed using a FORTRAN program. Figures 1; references 11.

Comparison of Gas Dynamic Models of Bodies in Hypersonic Flow

937F0104E Moscow PRIKLADNAYA MATEMATIKA I MEKHANIKA in Russian Vol 56 No 6, Nov-Dec 92 pp 1033-1038

[Article by S.V. Zhluktov, S.V. Utyuzhnikov, V.S. Shchelin, V.G. Shcherbak, Moscow; UDC 531.6.011]

[Abstract] Steady-state flow about the blunt nose of the Buran and Space Shuttle vehicles during their reentry and descent is considered and various gas dynamic models for describing the chemically nonequilibrium flows in these cases are compared; in particular, locally self-similar approximations of the Navier-Stokes equations of the chemically equilibrium and nonequilibrium total viscous shock layer (PVUS) and the model of the thin viscous shock layer (TVUS) are examined. The total system of stationary Navier-Stokes equations describing the flow of a multicomponent chemically reacting mixture of gases in the absence of external mass forces in a curvilinear system of coordinates is derived and reduced to a nondimensional form. The boundary conditions on the body surface are formulated ignoring the slip and temperature and concentration shocks. The system of parabolized Navier-Stokes equations is solved in the

framework of the local self-similar approximation on the stagnation line. The flow about reentering bodies is considered using three catalytic activity models. The findings show that the divergence between the models does not exceed 8% or 30K at an equilibrium surface temperature under the above flow conditions. The expediency of using the thin viscous shock layer model under gliding descent conditions is demonstrated. The authors are grateful to G.A. Tirskiy for discussions and constant interest in the effort. Figures 5; references 16: 11 Russian, 5 Western.

Analytical Calculation of Triaxial Gyro Stabilizer Drift Behavior

937F0104F Moscow PRIKLADNAYA MATEMATIKA I MEKHANIKA in Russian Vol 56 No 6, Nov-Dec 92 pp 1047-1049

[Article by S.V. Sokolov, Rostov-na-Donu; UDC 531.383]

[Abstract] The equations which describe the behavior of the platform's instantaneous angular velocity vector in a gyroscopic system of coordinates are derived for the platform of a triaxial gyroscopic stabilizer (TGS) located on the earth in the framework of the precession theory and on the assumption of a random polynomial dependence of the drift rate on the *g*-load. An approximation of these equations is considered on the basis of the gyro stabilizer properties and applications and the analytical dependence of the gyrostabilized platform drift rate on time is established. The smallness of absolute drift rate variations during the entire platform operation is used to find the possibility of analytically representing the solution of reduced equations. The possibility of ensuring the requisite representation accuracy of the true drift rate is checked by numerical simulation of the platform drift rate evolution. The findings make it possible to draw the conclusion that practical applications of the drift rate approximation are not only possible but are also expedient from the viewpoint of computation outlays. References 2.

Harmonic Wave Evolution During Propagation in Two-Phase Material

937F0105A Kiev PRIKLADNAYA MEKHANIKA in Russian Vol 28(38) No 9, Sep 92 pp 42-46

[Article by Ya.Ya. Rushchitskiy, Ye.V. Savelyeva, Mechanics Institute at the Ukranian Academy of Sciences, Kiev; UDC 539.3]

[Abstract] A physical phenomenon whereby a harmonic sound wave with an initially smooth profile, usually sinusoidal, evolves during propagation in a two-phase material and having traveled a certain distance, becomes continuous, i.e., acquires a steeper leading edge slope, then undergoes a phase reversal, is considered. This phenomenon is a major consequence of nonlinearity of the propagation medium and the wave's nonlinear self-action. Yet since only the dominant mode is excited in the medium while the second one becomes locked, under certain condition the wave may be regarded as linear and the interaction between the mode can be ignored. It is noted that unimodal representations are similar to a simple wave and can be denoted in Riemann's form. The phase conjugation time which is inversely proportionate to the phase velocity and wave peak-to-peak amplitude is derived. The behavior of the second mode acquired by the principal mode is observed. References 19.

Nonaxisymmetric Wave Processes in Stiffened Cylindrical Shell Under Longitudinal Impact

937F0105B Kiev PRIKLADNAYA MEKHANIKA in Russian Vol 28(38) No 9, Sep 92 pp 55-62

[Article by V.F. Meysh, Mechanics Institute at the Ukranian Academy of Sciences, Kiev; UDC 539.3:534.1]

[Abstract] The nonstationary behavior of a stiffened shell is considered allowing for the discrete placement of the stringers and rings under a longitudinal impact. In so doing, the cylindrical shell is treated as a system consisting of the skin and ribs rigidly braced to it along the lines of contact whereby the taut strained state of the shell and stiffening elements may be determined in the framework of Timoshenko's hypotheses. The contact conditions which link the skin surface and the centers of gravity of the stiffening element cross sections to the motion equations of the stiffened cylindrical shell are derived. The connection between the force and moments through displacement strain is examined and numerical algorithms for solving the wave process problem are formulated on the basis of the finite difference quantization of the variational equation and an explicit finite difference integration procedure. The numerical results are analyzed. It is noted that the wave pattern is nonaxisymmetric under due to the effect of the stiffening stringers and rings. Figures 3; references 13: 12 Russian, 1 Western.

Effect of Composite Material Properties on Stability and Initial Postcritical Behavior of Stringer-Stiffened Cylindrical Shells

937F0105C Kiev PRIKLADNAYA MEKHANIKA in Russian Vol 28(38) No 9, Sep 92 pp 62-68

[Article by N.P. Semenyuk, N.B. Zhukova, A.I. Morenko, Mechanics Institute at the Ukranian Academy of Sciences, Kiev; UDC 539.3]

[Abstract] A shell consisting of layers of a fiber-reinforced composite material with a given orientation angle to the generator line stiffened with stringers is considered assuming that the entire laminar structure is orthotropic. A special computer routine is used to analyze the effect of the composite properties on the stability parameters and initial postcritical behavior of various types of shell structures. This analysis is carried out from

the viewpoint of macromechanics according to which each shell monolayer consisting of fibers oriented in a particular way and held together by a binder is treated as an anisotropic homogeneous body. Two examples are considered: in the first, the effect of the composite properties on the critical load and postcritical behavior of shell from glass and boron plastic, boron-aluminum composite, and steel with L/R=1 with a varying number of ribs is examined; in the second, the behavior of critical loads and sensitivity of B-Al shells with L/R=0.5 as a function of the ratio between the skin and rib stiffness is investigated. One more analysis is carried out for examining the dependence of the bifurcation loads and postcritical behavior on the reinforcement direction of smooth and stiffened four-layered shells. The findings illustrate the effect of the composite properties on the critical loads and the character of postcritical behavior of stringer-stiffened laminar cylindrical shells under axial compression. Figures 5; tables 3; references 10: 7 Russian, 3 Western.

Stabilizing Uniform Rigid Body Rotation Around Principal Axis

937F0105D Kiev PRIKLADNAYA MEKHANIKA in Russian Vol 28(38) No 9, Sep 92 pp 73-79

[Article by A.M. Kovalev, Issa Salem Abdalla, Applied Mathematics and Mechanics Institute at the Ukrainian Academy of Sciences, Kiev and Science University, Sebha, Libya; UDC 531.38:62-50]

[Abstract] The movement of a rigid body relative to the center of mass under the effect of a reactive force is outlined and the system of equations of disturbed motion of the body around its first principal axis is derived. The stabilizeability of the system is considered and stabilization of uniform rotation is examined in a first approximation. To this end, linearized disturbed motion equations are derived in order to examine the controllability of the rotating body. Motion controllability in critical cases is analyzed and the sufficient controllability conditions are formulated on the basis of the theorem of local controllability of nonlinear self-contained systems. The equilibrium position stabilization is analyzed using the Barbashin-Krasovskiy theorem using kinetic energy as Lyapunov's function. The case of uncontrolled motion is examined separately. The conclusion is drawn that the system under study is either stabilizeable under certain conditions or nonasymptotically stable. In particular, it is stabilizeable in a linear approximation. The relationship between stabilizeability and controllability is studied. References 9: 8 Russian, 1 Western.

Examination of Stressed State of Three-Layered Cylindrical Shell Under Effect of Localized Loads

937F0106A Kiev PRIKLADNAYA MEKHANIKA in Russian Vol 28(38) No 10, Oct 92 pp 36-40

[Article by I.V. Polubinskaya, Mechanics Institute at the Ukrainian Academy of Sciences, Kiev; UDC 539.3]

[Abstract] The stressed state of hollow three-layer cylinders to which loads are applied in areas whose boundaries do not coincide with the coordinate lines is studied on the basis of the approach developed for solving static problems of three-layer axisymmetric shells. In so doing, the Kirchhoff-Love approach is adopted for the two rigid outer layers while the meridional, hoop, and tangential stresses in the inner filler layer are assumed to be equal to zero in the three-dimensional equations of the theory of elasticity. After the separation of variables, the taut strained state of the shell under the effect of asymmetric, including localized, loads is reduced to integrating a series of boundary value problems for a system of eighteenth-order ordinary differential equations. A robust numerical method of discrete orthogonalization ensuring a high accuracy of the results is used to solve the boundary problem. The example of a shell loaded by a uniform normal pressure distributed over an elliptical area is considered. The stress behavior along the meridian in isotropic and orthotropic shells and the tangential stress distribution through the cylinder walls are plotted. For illustration, the problem of a three-layer cylinder loaded by concentrated forces along circular lines is solved. The physical validity of the method is confirmed by the consistency of the findings with published data. Figures 3; tables 1; references 11.

Application of Timoshenko-Type Theory in Cubic Approximation to Problem of Initial Postbuckling Behavior of Composite Shells

937F0106B Kiev PRIKLADNAYA MEKHANIKA in Russian Vol 28(38) No 10, Oct 92 pp 41-46

[Article by N.B. Zhukova, N.P. Semenyuk, Mechanics Institute at the Ukrainian Academy of Sciences, Kiev; UDC 539.3]

[Abstract] The difficulty of Kirchhoff-Love theory realizations under offset straining and the relative simplicity of the Timoshenko-like theory of nonlinear straining of curvilinear rods prompted an investigation into the loss of stability (i.e., buckling) and initial postbuckling behavior of cylindrical shells of an unequal length which, due to the diversity of the possible forms of buckling, is a test problem not only for checking various design methods but also for estimating the accuracy of various theoretical models. All formulas are represented in a nondimensional notation and the displacements are normalized. The expressions for the curvature and torsion increments in a laminar shell contain nonlinear terms to the third power, so the approximation is referred to as cubic. The findings also show that the quadratic version is also suitable for describing the initial postbuckling behavior yet one should exercise caution in using it. For illustration, the parameters and coefficients of a 15-layer glass plastic laminate shell are examined in detail. Tables 2; references 19: 17 Russian, 2 Western.

Analysis of Axisymmetric Thermoelastoplastic State of Laminar Branching Shells Under Repeat Loading Conditions

937F0106C Kiev PRIKLADNAYA MEKHANIKA in Russian Vol 28(38) No 10, Oct 92 pp 47-52

[Article by A.Z. Galishin, V.A. Merzlyakov, Mechanics Institute at the Ukrainian Academy of Sciences, Kiev; UDC 539.374]

[Abstract] The axisymmetric elastoplastic state of a laminar branched shell under nonisothermal repeat loading is discussed; in particular, a branched axisymmetric shell, whose coordinate surface meridian is represented in the form of the meridian of the principal shell with branching nodes at each of which several coordinate meridians of open branches converge, is considered. Each branch is a thin axisymmetric shell consisting of orthotropic layers with a variable thickness along the meridian and each branch is referred to a local curvilinear system of coordinates. The initially nonstrained shell is loaded simultaneously by force and thermal actions; the load relieving processes are examined too. The thermoelasticity problem is solved in a quasistatic formulation using linear geometrical and static correlations of laminar shells based on Kirchhoff-Love hypotheses for the entire stack of layers. For illustration, the thermoelastoplastic state of a laminar disc mated with a thin-walled shaft shaped as a cylindrical shell is considered. Figures 6; references 6.

Thermosensitive Composite Shell Stability

937F0106D Kiev PRIKLADNAYA MEKHANIKA in Russian Vol 28(38) No 10, Oct 92 pp 52-57

[Article by L.P. Khoroshun, D.V. Babich, Mechanics Institute at the Ukrainian Academy of Sciences, Kiev; UDC 539.3]

[Abstract] The lack of data on the stability of shells made from thermosensitive composites, and particularly the impact on the critical shell parameter analysis of taking into account the dependence of the thermoelastic characteristics of composites with various structures on the heating temperature, are discussed. The effect of this factor on the stability of cross-reinforced cylindrical shells is examined on the assumption that the properties of the components depend linearly on the shell temperature. The effective thermoelastic characteristics of the stack of layers forming the laminar shell are determined using the structural method based on the theory of random functions and the formulae for transforming the monolayer characteristics with a change in the direction of the coordinate axes by an angle between the reinforcing fiber direction and the shell meridian. The critical loads are calculated by the variational method. The character of the effect of thermal sensitivity on the shell stability is illustrated using the example of boron-epoxy plastic shells under various resting and restraining conditions. The two factors related to the thermal action affecting the stability of shells are identified: the peculiar features of the basic stressed state contributed by heating and the dependence of the thermoelastic properties of the material on the heating temperature. Figures 2; tables 4; references 8.

Quantitative Estimates of Intensity of Solid Particle Entrainment From a Streamlined Surface

937F0108A Tashkent DOKLADY AKADEMII NAUK RESPUBLIKI UZBEKISTAN in Russian No 2, Feb 92 (manuscript received 3 Apr 91) pp 14-15

[Article by A.A. Makhmudov, I.K. Khuzhayev, B.R. Toshov, and T.R. Yuldashev, Institute of the Mechanics and Seismostability of Structures imeni M.T. Urazbayev, Republic of Uzbekistan Academy of Sciences; UDC 532.529+631.459]

[Abstract] The formation of a two-phase medium when a flow circulates around an eroded surface is of practical concern in relation to predicting the scales of erosion processes and developing effective methods of combating erosion. Under the effect of a turbulent boundary layer, the solid particles of the underlying surface may either remain stationary or else be entrained. The motion of the entrained particles (dragged, rippling, suspended) is in turn determined by the flow's parameters and by the physicomechanical properties of the particles constituting the streamlined surface. An experimental study examined the intensity of particle entrainment from a streamlined surface in cases where solid particles are entrained in a suspended state. The quantity of entrained solid particles as a function of flow parameters was determined on a wind tunnel unit developed by the Aerodynamics of Natural Processes Laboratory of the Institute of Mechanics and Seismostability of Structures of the Uzbekistan Academy of Sciences. Pelletized particles of grassy-meadow sandy loam soil with a granulometric profile ranging from 1.4×10^{-4} to 1.5×10^{-3} m and density of 2,720 kg/m^3 were studied. The particles were entrained under the effect of a turbulent boundary layer formed in the working section of the wind tunnel and passed around a plane wafer. A groove 0.06 m wide and 0.006 m deep was made in the wafer a distance of 0.3 m from its edge to mount the soil specimen carriers. The carriers were mounded so that the particles were flush with the wafer's surface. The gravimetric method was used to determine the amount of particles entrained. The experiments were performed at oncoming flow speeds of 3.0 to 12 m/s. The change in intensity of solid particle entrainment as a function of the coefficient of mobility was plotted for the initial, transient, and stabilized entrainment modes studied. The data fell into three segments that each approximated straight lines; the initial, transient, and stabilized entrainment modes were found to have powers of 3/2, 5, and 3, respectively. Overall, the experiments confirmed the well-known law of the hydrodynamics of bottom drift, i.e., the intensity of particle entrainment is directly proportional to volume velocity. The slight deviation from this pattern observed in cases of low coefficients of mobility was explained in terms of the fact that the instantaneous

values of the velocity of the flow onto a solid particle in a well-developed mode of particle entrainment can always facilitate transportation. The same cannot be said of the initial and transient modes, which act as incubation periods for well-developed particle entrainment. Figure 1; references 5: 4 Russian, 1 Western.

Optimal Control of Almost Periodic Motions

937F0087A Moscow PRIKLADNAYA MATEMATIKA I MEKHANIKA in Russian Vol 56 No 5, Sep-Oct 92 (manuscript received 32 Sep 91) pp 837-846

[Article by A.G. Ivanov, Izhevsk; UDC 531.36:62-50]

[Abstract] The set of almost periodic functions in the Stepanov sense is considered in an n-dimensional R^n Euclidean space with Hom(R^n) space of linear operators and a comp(R^n) set of compact subspaces, B(R,Y) being the set of almost periodic functions in the Bor sense. Optimal control of almost periodic motions is considered, the necessary conditions for extremum are established in the form of Pontryagin's maximum principle for this problem after its convex expansion. For this purpose are introduced the APM space of partial-valued almost periodic transformations and the linear frm(U) space of Radon measures in the R^n space, whereupon is also applied the concept of exponential dichotomy. Three relevant theorems with an applicable corollary to one are stated. They are followed by a fourth theorem with an applicable corollary, this theorem being proved with the the aid of four lemmas. A fifth theorem is then proved which validates convex expansion of this optimal control problem for almost periodic functions. References 20.

Use of First Integrals for Estimating Overall Capability of Optimal Control Systems

937F0087B Moscow PRIKLADNAYA MATEMATIKA I MEKHANIKA in Russian Vol 56 No 5, Sep-Oct 92 (manuscript received 2 apr 91) pp 847-853

[Article by V.Ye. Berbyuk, Lvov; UDC 62-50]

[Abstract] The motion of a nonstationary multidimensional nonlinear dynamic system is to be controlled according to the equation dx/dt = f(x,t)+ B(x)u(x,t), where $x = (x_1,...,x_n)$ is an n-dimensional vector of phase coordinates and $u = (u_1,...,u_m)$ is an m-dimensional vector of controlling forces, f(x,t) is a given v(nX1)-dimensional vector function and B(x) is a given (nXm)-dimensional matrix. As criterion for optimal control is selected minimum of an integral energy functional J[x(.),u(.)], the problem thus being to obtain the upper-bound estimate of minimum necessary energy expenditure J* for moving such a system from its initial state $x(0) = x_0$ at time t = 0 to its final state $x(T) = x_T$ within time T. This estimate is obtained by using the first integrals of the equations of free motion dx/dt = f(x,t) (u = 0). For validation of the proposed method, a theorem is proved which states: if a first integral of those equations is a function w(x,t) such that the corresponding integral energy functional G[x(.)] is defined in the entire set of admissible controlled processes and if the solution to the Cauchy problem not only exists but also satisfies both boundary conditions (x_0;x_T), then $J^* \leq w(x_0,0) - w(x_T,T)$. The method is demonstrated on estimating the minimum necessary energy expenditure for bringing a rotating axisymmetric solid body to rest. From that first theorem follows immediately a second one stating that $J^* \leq w(x_0,0) - w(x_T,T)$ also for moving such a dynamic system from an arbitrary initial state to a final phase state $x_T = x_w(T)$ within time T when $x_T = x_w(T)$. This is demonstrated on estimating the overall capability of an energy-optimal control system for the motion of an artificial satellite in the Newtonian gravitational field. A procedure is outlined for obtaining all first integrals of the equations of free motion, and thus refining the estimate J* by referring it to min for all w in set W[x(x,t)]. As a third example is considered a control dx/dt = A(t)x+ B(t)u, where A is an nXn-dimensional matrix and B is an nXm-dimensional one. As a fourth example is considered a dynamic system dx/dt = f(x,t)+ u with an invariant norm, where both vectors x and u are nX1-dimensional and the equations of its free motion dx/dt = f(x,t) (u = 0) has a first integral: Euclidean norm of the phase vector x References 15.

Method of Optimal Control of Motion of Continuously Perturbed Dynamic Systems

937F0087C Moscow PRIKLADNAYA MATEMATIKA I MEKHANIKA in Russian No 5, Sep-Oct 92 (manuscript received 30 Mar 92) pp 854-863

[Article by R. Gabasov, F.M. Kirillova, and O.I. Kostyukova, Minsk; UDC 62-50]

[Abstract] The linear optimum control problem for a dynamic system $J(u) = h'_0x(t^*) \rightarrow \max$, dx/dt = Ax+ bu, $x(0) = x_0$, $Hx(t^*) = g$, $(t) \leq 1$ ($t \in T$, $x \in R^n$, $g \in R^m$, $u \in R$) subject to continuous perturbations is considered, the control u(t) for it being sought in the class of piecewise-continuous functions u(t) ($t \in T = [0,t^*]$). Optimal position feedback control $u^0(x,t)$ ($t \in T$) is selected in preference to optimal program control u^0 (t) ($t \in T$), because such a control can respond to many otherwise unaccounted for perturbations w(x,t) ($t \in T$) so that the trajectories $x^*(t)$ ($t \in T$) of the system dx/dt = Ax + $bu^0(x,t)$ + w(t), $x(0) = x_0$,continuous perturbations are assumed to be sufficiently regular, in the probabilistic sense, and to obey certain though unknown laws so that the functions z^w (t) ($t \in T$) characterizing the drift of trajectories can be closely approximated in the class of piecewise-parametric functions. In addition to a regulator, real-time control requires a predictor which generates the solution to the problem of trajectory drift in that class of piecewise-parametric functions while the regulator starts out in the relay mode of optimal program control $u^*(t)$ ($t \in T$), $^*(t) \equiv 1$ ($t \in T$). Following an outline of both predictor and regulator algorithms, they are applied to optimal control Int u(t)dt from t = 0 to t = 4π

→ min of the oscillatory motion $d^2x/dt^2 + x = u$ ($t \in [0;4\pi]$) with $x(0) = 0.703$, $dx/dt = -0.955$, $x(4\pi) = 0$, $dx/dt(4\pi) = 0$, $0 \leq u(t) \leq 1$. The authors thank N.V. Balashevich for making the calculations. References 11.

Natural Vibrations of Moment-Free Spherical Shell

937F0087D Moscow PRIKLADNAYA MATEMATIKA I MEKHANIKA in Russian Vol 56 No 5, Sep-Oct 92 (manuscript received 12 Feb 91) pp 869-871

[Article by V.M. Lyubimov and G.I. Pshenichnov, Moscow: UDC 539.3: 534.1]

[Abstract] Natural vibrations of a moment-free spherical shell under two elastic constraints at opposite ends are described by a system of three fourth-order ordinary differential equations of motion relating angular displacement components φ, θ to linear displacement components u,v,w and two algebraic equations for the normal meridional force N_1 proportional to u and the shearing force S proportional to v respectively, Hooke's law being expressed appropriately for each force: N_1 proportional to strain $e_1 + se_2$ and force S proportional to frequency ω. This system of equations is solved separately for every possible number n of modes propagating around the parallel. It is solved by separation of variables, one solution which is regular at the vertex of the shell being thus obtained for the three linear displacement components u,v,w in terms of associated Legendre functions P[lower index m, upper index n](θ) with a coefficient C_{mn} each (m - roots of the quadratic eigenvalue-problem equation). Two classes of solutions are shown to exist for such a shell: (1) with nonzero all three u,v,w displacement components, (2) with nonzero both tangential u,v displacement components only. For each class that system of fourth-order ordinary differential equations reduces to second-order resolvent equations and thus has two linearly-independent solutions in each case, the second solution being a regular one in class (2) only. As an example are considered axisymmetric vibrations of a shell in the shape of a spherical dome. References 2.

Twisting of Hollow Circular Cylinder with Variable Shear Moduli

937F0087E Moscow PRIKLADNAYA MATEMATIKA I MEKHANIKA in Russian VOl 56 No 5, Sep-Oct 92 (manuscript received 26 Nov 91) pp 871-873

[Article by G.I. Nazarov and A.A. Puchkov, Kiev; UDC 539.3]

[Abstract] Twisting of an anisotropic nonhomogeneous solid of revolution has been described by a system of two elliptic differential equations in displacements and stresses in a cylindrical system of coordinates (r,θ,z), this system of equations having also been solved in the form of complex infinite integral and differential series for the general case of a shear modulus arbitrarily varying along the radius and mixed boundary conditions at the lateral surface (G.I. Nazarov and A.A. Puchkov; PRIKLADNAYA MATEMATIKA I MEKHANIKA Vol 36 No 6, 1972). Here a general solution in the form of a finite integral operator Int f(z)dz is obtained for a hollow cylinder with a radially varying shear modulus so that the stress function becomes $\psi = \mathrm{Re}[(\alpha(r)f(z) + A \int f(z)dz]$ and the displacement function becomes $\varphi = \mathrm{Im}[\beta(r)f(z) + B \int f(z)dz]$, f(z) being an arbitrary function of the complex variable z. For specificity is considered the case of $A = 1$ and $B = 0$. For solution of the boundary-value problem for a hollow cylinder, f(z) is represented in the form of a converging series: $\Sigma\, n^{-1}(a_n e^{n\omega z} + b_n e^{-n\omega z})$ from $n = 1$ to $n = \infty$. The problem is solved thus for a cantilever hollow nonhomogeneous cylinder subject to twisting moment at the free end and with mixed lateral boundary conditions: a given superficial force at the outside surface and a given displacement at the inside surface. Both stress and displacement functions are obtained by extraction of the respective real and imaginary components. The boundary conditions for the stress function are then stipulated in terms of its gradients and those for the displacement function in terms of linear displacement $v = r\varphi$ at the inside surface. References 4.

Enhancing the Safety of Ship Nuclear Power Plants

937F0089B St. Petersburg SUDOSTROYENIYE in Russian No 1, Jan 92 pp 11-14

[Article by L.P. Sedakov and A.V. Vorontsov; UDC 629.12.03-8:621.039]

[Text] Nuclear power and its use in power generation in power plants and on ships are the result of objective engineering progress and are without alternatives in the near future in a number of areas of technology.

In large-scale power generation at power plants this is primarily due to the familiar problems of the economy, the decreasing reserves and increasing costs of recovering and transporting hydrocarbon fuel, and the constant and inevitable ecological and environmental consequences of hydro- and thermal electric power plants. Even given normal operating conditions, the ecological effects of thermal power plants on the environment are, for example, associated with the emission of toxic materials and carbon dioxide into the environment and with the consumption of atmospheric oxygen when fuel is burned. Even though so-called "small-scale power generation" and transport (especially motor vehicle transport) are currently the major contributors to environmental pollution, existing data[1] indicate that each year about 100 million metric tons of toxic materials is released into the atmosphere in the USSR. This does not include the 17 million metric tons of CO_2 released by Ministry of Power and Electrification [Minenergo] enterprises.

In ship power generation, the use of nuclear reactors has made it possible to achieve a virtually unlimited navigation range in connection with the ships' high power availability. This is especially necessary in the case of ice breakers, sea transport vessels operating in Arctic regions, and submarines. It is hardly possible to gear vessels and ships of these classes to the familiar alternatives such as renewable power sources that may in the future be considered in power generation at power plants, such as wind power, solar power plants, sea and ocean tides, etc.

The high performance qualities of nuclear power plants have been clearly demonstrated during the course of their more than 30 years of operation on domestic nuclear ice breakers (seven). Even the first few years of the ice breaker Lenin's operation showed its national economic effectiveness in lengthening Arctic navigation periods and increasing the number of hauls.

The data[2] presented in Table 1 confirm the very broad scales of the use of nuclear power plants in naval fleets.

Table 1. Nuclear Reactors in the Naval Fleet

Ship Type	United States	USSR	Great Britain	France	People's Republic of China	Total
Aircraft carriers	18	0	0	0	0	18
Cruisers	18	6	0	0	0	24
Submarines with ballistic missiles	33	122	4	6	2	167
Same but with winged missiles	0	78	0	0	0	78
Torpedo submarines	92	149	17	4	4	266
Other*	1	25	0	0	0	26
Total	162	380	21	10	6	579

*Including icebreakers and submarines with nonweaponry status. Not including 28 reactors on submarines awaiting write-off.

Nevertheless, the incidents that have taken place in power generation at foreign and domestic power plants, above all the accident at the Chernobyl Nuclear Power Plant and the emergencies that have developed for a variety of reasons during the construction, repair, testing, and operation of ship nuclear power plants, have made the problem of the safety of these nuclear power plants much more acute. In view of the consequences of the accident at the Chernobyl Nuclear Power Plant, the problem has acquired not only engineering significance but social significance as well. As a result, several specialists in related sectors and the public have attempted to demand unlimited safeguarding of the safety of the nuclear power source or even a total ban on its use. This type of integrated evaluation and conclusions are, however, not generally based on an analysis of the special features of the structural engineering solutions, operating conditions, and measures taken to safeguard vessels or address the consequences of the development of likely accident situations.

In the general case, the concept of "clean" and "dirty" technologies is relative; however, during normal operation, nuclear power plants may be classified among ecologically "clean" technologies because they do not demand anything from the environment and do not discharge anything into it (except for the heat released from the final cooler, which is isolated from the reactor by at least two intermediate loops). A nuclear power plant of any type (plant or ship) is safe for its personnel and the environment if standard engineering and sanitary-hygiene requirements are adhered to.

Domestic ship power generation has, for example, been created with consideration for meeting the safety requirements, including international requirements, that have been in effect for the defined period of the more than 30-year history of the construction of various types of nuclear power plants.[3,4,5] It is largely for this reason

that during the operation of ship nuclear power plants, the incidents that have occurred as a result of the use of a nuclear power source have had no comparatively grave consequences even though the total output of nuclear power plants in the fleet has amounted to several thousand reactor-years.

When formulating the problem of creating a modern ship nuclear power plant with enhanced safety, it is important to emphasize that it is fundamentally impossible to achieve absolute reliability in any complex power generation system created on the basis of compromises between mutually exclusive requirements, regardless of the type of fuel, because of failures in equipment components, erroneous actions on the part of personnel, or extraneous factors such as damage to the ship's hull during navigation. For nuclear power plants, the consequences of such a situation are exacerbated by the specifics of the fuel and are linked to the possibility of the occurrence of a nuclear accident as a result of a disruption in the monitoring and control of the chain reaction, discharge of heat from elements containing nuclear fuel, or the formation of a critical mass during refueling. It is necessary to consider the fact that the vessel in and of itself is an object of potential danger. On a ship all accident situations resulting from external (navigational damage) or internal (fire and explosion) causes, functional failures of equipment, or incorrect actions by personnel may build upon one another over time, and their consequences may be exacerbated.

Proceeding from the aforesaid and in consideration of current requirements, one can formulate the definition of the term "ship nuclear power plant with enhanced safety" as the ability of the system "nuclear power plant-ship" to guarantee that the radiation consequences resulting from any accident situations related to the ship's or the nuclear power plant's operation or the simultaneous occurrence thereof will conform to normative requirements and will virtually exclude harm to personnel, the region's population, and the environment.[6]

In this case, the concept of a ship nuclear power plant with enhanced safety as a goal and as a system of an approach to solving the problem of creating a nuclear power plant possessing such properties should include the following three safeguarding factors:

—preventing the occurrence of any types of factors in the system "vessel-nuclear power plant" that may potentially ultimately result in the disruption of the reactor's core as a result of the development of a nuclearly risky situation related to a breakdown in the monitoring and control of the chain nuclear reaction or heat release from the core's fuel elements;

—in cases where such factors (even those with a low-risk) have arisen, the nuclear power plant should, as the ship's power generation system, limit the development of a nuclearly risky situation and prevent a disruption of the reactor's core;

—if an accident associated with damage to the reactor's core and the escape of radioactive materials or ionizing radiation has occurred anyway, the system "vessel-nuclear power plant" should, by virtue of means that are internal in relation to the environment, localize the radioactivity in the system itself and prevent its propagation beyond the ship's confines.

A ship nuclear power plant with enhanced safety should therefore be

—resistant to external actions and ship accidents in all accident situations including sinking;

—capable of withstanding functional disruptions and accidents as a result of failures in its component equipment and elements and monitoring, control, and protection systems;

—protected from erroneous actions by personnel;

—equipped with shielding or emergency safety barriers and devices and systems to localize the consequences of likely accidents that are dangerous from a radiation standpoint all the way up to total prevention of the propagation of radioactive products beyond the confines of these barriers.

Problems of assessing the reliability and safety of a reactor unit as a potential nuclear accident source and the soundness of the shielding principles and methods of localizing the development of an accident on a ship are of primary importance on the plane of the formulated concept of a modern ship nuclear power plant with enhanced safety. The reactor units in the ship nuclear power plants that have been created possess a number of objective prerequisites that permit a priori confirmation of their enhanced safety compared with reactors at nuclear power stations.

The main differences between ship reactors and type RBMK channel-type reactors used at the Chernobyl Nuclear Power Plant[7] that in turn dictate the probability of the occurrence and development of an accident such as the one that occurred may be briefly summarized as follows:

—unlike reactors of the RBMK type, all ship reactors have an outer vessel designed for more than twice their operating pressure and containment shells that either confine or completely localize the escape of radioactivity when the working loops leak;

—ship nuclear power plants are based on a two-loop circuit, which excludes radioactive contamination of the working steam during normal operation;

—a reactor runaway due to an uncontrolled increase in temperature in the core is impossible in ship nuclear power plants, and the core does not contain any flammable materials such as graphite as RBMK reactors do;

—unlike nuclear power stations, ship nuclear power plants are designed with consideration for continuously acting loads related to swelling of the sea, interaction of the ship's hull with ice, and possible collision with another ship or grounding;

—the primary loop of ship nuclear power plants is smaller and has much shorter large-diameter communicating lines, which significantly reduces the probability of their leaking. This, coupled with their relatively lower power level, makes it possible to set up reliable emergency cooling of cores in the event of coolant leaks.

From the standpoint of their physical properties, ship reactors thus guarantee a high safety level. In view of this fact, accidents such as the Chernobyl Power Plant and with the same consequences cannot happen in ship water-moderated water-cooled reactors. In view of the special characteristics mentioned above, ship nuclear power plants also differ from nuclear power plants based on pressure vessel-type water-moderated water-cooled reactors such as the VVER-440 and VVER-1000, albeit to a lesser degree.

However, the requirement that a ship nuclear power plant possess enhanced safety, as formulated above, presupposes that the system "nuclear power plant-ship" will also remain stable in the event of hypothetical or worse-than-design accidents, which previously was only estimated in the design stage.

It has frequently been proposed that the probability of an accident be used as a criterion of safety level when judging a nuclear power plant's safety level. The term "accident probability" means the probability of an accident with disruption of the core not exceeding, for example, 10^{-6} to 10^{-7} per reactor-year; nevertheless, such an estimate can hardly be convincing in view of the great uncertainty of the starting data, the significance of subjective estimates, and even the very essence of the probability of events as a statistical quantity. If one is speaking of the probability of one accident, that accident may happen in 1 year or in 100,000 years. The probabilistic approach may therefore be used for relative comparison of the safety of nuclear power plants when comparing different versions of units with one another.

The main task facing designers, builders, and operators when safeguarding a nuclear power plant nevertheless remains the creation of conditions for the minimum possible probability of the occurrence of various types of accident situations and the development of practical measures to prevent the escape of radioactivity into the environment. The problem of localizing the development of an accident on a ship must be solved in a number of directions. The key, however, is what is called "in-depth" protection, which presupposes a number of protective barriers along the path of the radioactivity's propagation from its source to the environment.[8] Any disruption in the integrity of these protective barriers, whether at the same moment (as the result of some external event) or sequential, is a sign of a worse-than-design or hypothetical accident. Consequently, the more initial events a power plant and ship withstand without any spread of the accident's consequences beyond the bounds of design accidents, the safer it is.

We will consider possible causes of a disruption in integrity and measures helping to fulfill the functions of protective barriers.

The term "first protective barrier" refers to the fuel assembly and primarily to its cladding. Despite the fact that a great deal of attention is always paid to making the fuel assembly leaktight, it cannot be kept completely leaktight during the course of a refueling cycle for technological reasons owing to less-than-optimal profiling of the releases of energy in the core and the inconsistencies in actual and design utilization models. Leakages of a limited number of fuel elements, as determined by the permissible activity of the coolant of the primary loop, are therefore tolerated during operation.

During accidents related to a disruption of heat release from the fuel elements or an unauthorized increase in energy release reaching the outbreak of a spontaneous chain reaction, there is a loss of the claddings' stability and even a disruption of the core within the confines of its cooled geometry. The fission products released from the fuel assembly enter the coolant, and the coolant's activity may increase by three to five orders of magnitude. Ensuring that the first protective barrier is maintained therefore requires providing equipment guaranteeing a halt of the fission reaction and reliable heat removal from the fuel elements in all emergency situations.

A loss-of-coolant accident is critical here. Because this type of accident is directly linked to the integrity of the second protective barrier (vessel structures, reactors, and communicating lines containing the coolant of the primary loop), we will consider it in somewhat greater detail. A loss-of-coolant accident in the primary loop is potentially the most dangerous accident for two reasons. The first is because when coolant is either completely or partially lost, heat removal from the fuel elements is disrupted, and depending on the scale of the loss-of-coolant accident, the fuel elements may begin to leak or even rupture and result in the escape of fission products beyond the confines of the primary loop. Second, the release of a large amount of the energy accumulated in the coolant of the primary loop results in a sharp increase in the parameters of the medium in the reactor room, which may facilitate the further development of the accident and the escape of radioactive products into adjacent rooms and the environment.

It is precisely these two factors that have served as the basis for designating such an accident a maximum design accident, which is to say an accident involving a leak in the primary loop. The results of this type of accident are analyzed when a nuclear power plant is being designed, and safeguarding measures are taken.

The following steps may be taken to prevent a fuel assembly from rupturing during a loss-of-coolant accident:

—eliminate the possibility of a total loss of coolant in the event of a leak of the primary loop (preservation of a water residue in the reactor vessel sufficient to cover the core at the end of the coolant leak process). This is achieved by design and layout decisions, for example, by using a single-block steam-generating unit, which makes it possible to reduce the probability of a leak of the primary loop by three to four orders of magnitude. The rational selection of systems servicing the reactor by reducing the number and length of the pipelines making up the piping and by locating the pipelines' inlets in the upper part of the reactor vessel (preferably in the hot branch of the circulation loop) will also help. The scale of a possible leak may be limited by installing passive devices in potentially dangerous pipelines to either affect the flow rate during an accident or halt it completely. The possibility of chilling the coolant, even in situations where failures pile up on one another (for example, a loss-of-coolant accident plus a feedwater stoppage), should also be provided.

—provide emergency flow testing of the reactor vessel by passive systems, as well as by active nuclear power plant equipment, including that based on a return principles or vessel-wide systems.

Another equally important aspect of the problem of maintaining the integrity of the first protective barrier is that of ensuring emergency cooling of the unit in the event of a loss of the capability of normal cooling through the standard systems, which may occur if a unit experiences a total power loss. To accomplish this, greater use should be made of passive emergency cooling systems using natural physical processes to function (for example, natural circulation of coolants or gravity pressure-type systems). Another possible example is flow-testing a steam generator by using the reserve of water in the deaerator, subsequently evaporating it in the steam generator, and then discharging the steam into the atmosphere. Pneumatic-hydraulic tanks may be used for this purpose.

Systems based on principles of natural circulation of coolants are preferred owing to their practically unlimited duration of operation.

Reactivity accidents caused by unauthorized or erroneous movement of control elements may result in a distortion of the energy release fields or flash of energy release in the core and, consequently, in the superheating of the fuel elements and leakage of their cladding. As was indicated above, even though modern ship reactors possess high internal "self-protection" throughout their entire interval of operating temperatures, the problem of finding the optimal value of the negative reactivity coefficient (which determines a reactor's dynamic characteristics in addition to its self-protection characteristic) still remains critical.

The need to reduce the physical mass of the individual parts of compensating lattices, which is objectively contradictory to design and layout decisions (specifically to the layout of the control and protection system's drives), is becoming increasingly obvious. On the other hand, the graduated movement of compensating groups with a prohibition against continuous lifting should be be given broader consideration.

The requirement of guaranteed insertion and reliable fixation of absorbing elements in the core so as to prevent them from moving when the spatial position of the vessel changes, when the reactor is uncovered, or in a number of other operations must become a necessary safety condition.

As was already mentioned, a stable and strong reactor vessel along with the piping of the systems of the PPU containing the coolant of the primary loop is the second protective barrier. The reactor vessel itself is a very reliable structure with a leakage probability that is, according to different estimates, very low (from 10^{-12} to 10^{-8}/y).[8] The probability of ruptures of the pipelines of the primary loop is significantly higher and is estimated at 10^{-3} to 10^{-2}/y, which has been confirmed by actual operating experience. The reasons for such situations are many, but they are basically reduced to flaws developed during the process of their manufacture and installation, overpressurizaiton, corrosion processes, and possible external effects.

The third protective barrier on the path of the propagation of radionuclides when the first two barriers are broken is the stable and strong protective containment designed to accept the energy accumulated in the coolant of the primary loop. From a design standpoint, it may be a part of the ship's hull structures, or it may be separated from them by compliant members and foundations excluding the transmission of strains from the vessel hull to the containment shell.

The containment shell may be equipped with systems to remove or store the energy of accidentally leaked medium from the space of the containment. This is advisable from both technical-economic and radiological standpoints. Such systems, which are designed to reduce the maximum possible pressure increase, should be passive (for example, condensation-type pressure suspension systems), and the systems designed to normalize the radioactive situation may be active-type systems (consequence systems) activated by personnel (for example, sprinkling systems to spray the containment shell).

The requirements imposed on the containment shell with regard to its leaktightness are very stringent because it is what dictates the radiation consequences of an accident. In the event of a maximum design accident, for example, even if the first protective barrier remains

intact, the amount of leakage must not exceed 1% of the volume per day. This is precisely the reason behind attempts to reduce the thermophysical consequences of an accident.

For ship nuclear power plants, those ship compartments that are directly adjacent to the containment shell and that either completely or partially surround it are generally considered a fourth protective barrier. The system of such compartments form a protective enclosure for which density requirements are imposed. The main purpose of this system of compartments is to collect leakages of radionuclides from the containment shell and subsequently remove them, thereby preventing the propagation of activity to the ship's other compartments.

The aforesaid relates to the problem of localizing and reducing the consequences of accidents caused by internal functional distruptions in a nuclear power plant's operation. In the case of ship nuclear power plants, a different spectrum of external effects that may reach the nuclear power plant is also characteristic. This includes various types of navigational situations and collisions, cargo explosions, the actions of nature, etc. The structural protection of the ship's hull is provided to protect the nuclear power plant in such cases. The problems of guaranteeing that protective barriers remain intact if a ship is destroyed demand special attention. For this purpose, for example, systems to flood the containment shell are used, and the behavior of the equipment of a nuclear power plant when flooded and the cooling of a unit are subjected to in-depth analysis.

Overall, solving the problem of ship nuclear power plant with enhanced safety requires an integrated approach in all of the stages of its creation. In addition to the problems that have been examined, the following should be guaranteed:

—quality of design based on the use of proven methods and technical materials, as well as by developing the plant's components and systems on models, mockups, and benches and analyzing their operating conditions and probable design and hypothetical accidents with implementation of the principles of "in-depth protection";

—quality of construction and, above all, adherence to the requirements in technical standards documentation, high technological discipline, and the use of monitoring and testing methods;

—quality of service, dictated above all by the presence of trained personnel capable of responsibly executing operating instructions and service procedures, including repair and refueling. It is also important that control stations be ergonomically designed and that modern diagnostic monitoring systems be used so that personnel can gather information and take the necessary actions;

—survivability of the ship carrying the nuclear power plant and the plant itself by making the ship capable of withstanding navigational, natural, and other unlikely operation-related accidents resulting in damage to or sinking of the ship, as well as by using rational methods of configuring the nuclear power plant's components and backing them up.

—development of optimal (both economically and ecologically) principles of taking a ship out of service after its service life has expired so as to recover and bury the spent fuel and those nuclear power plant components, units, and equipment with enhanced radioactivity.

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Conceptual Design of Research Manned Submersibles With a Diving Depth of More Than 2,000 Meters

937F0089A St. Petersburg SUDOSTROYENIYE in Russian No 1, Jan 92 pp 7-9

[Article by V.T. Shepel; UDC 629.127.4.001.2]

[Text] The amounts of crude minerals being recovered is currently increasing, and their progressive depletion on dry land has stimulated the assimilation of the World Ocean's useful mineral deposits at greater depths.[1] Manned submersibles are extremely feasible for prospecting for useful minerals at depths of 2,000 to 6,000 meters. Several manned submersibles with a working diving depth H_p greater than 2,000 meters (Table 1) have already been built throughout the world.

Table 1. Characteristics of Research Manned Submersibles With a Working Diving Depth of More Than 2,000 Meters

Craft Name (Producer-Country)	Working Diving Depth, m	Weight D, t	Speed v_s, knots	Crew Size n_{cr}, men	Cruising Capacity With Respect to Power Resources t_a, h	Main Dimensions		
						Length, L, m	Width B, m	Height, H, m
Siana (France)	3,000	8.3	3.0	3	5	5.7	3.0	2.1
Alvin (United States)	3,500	13.5	4.0	2	5	6.7	2.4	2.7
Nautile (France)	6,000	18	2.5	3	13	7.6	2.7	3.2
Mir (Finland)	6,000	18.7	5.0	3	10	7.8	2.9	3.2
Sea Cliff (United States)	6,000	25.4	2.5	3	8	9.1	3.6	3.9

Those manned submersibles that have been built in the past few years, specifically the Nautile and Mir, are especially interesting.

The Nautile submersible was built in 1984 on a wharf in the French city of Toulon.[2] It can carry a payload weighing 0.2 metric tons not counting its crew and numerous standard instruments and pieces of equipment. The Nautile has a spherical pressure hull 2.1 m in diameter with a walls 65 to 90 mm thick. It is made of a titanium alloy, and has three illuminators measuring 120 mm in diameter. Its outer hull is made of a composite material and contains about 9 m^3 of syntactin (spherical plastic). The submersible is equipped with two manipulators with remote control from the pressure hull. In order to accelerate surfacing in the event of an emergency, the submersible is capable of dumping its cast iron shot ballast (total weight, 1 metric ton), its two main storage batteries (total weight, 1.5 metric tons), both its manipulators (total weight, 0.16 metric tons), and the 0.3 metric tons of mercury that trims the manned submersible in its underwater position.

The distinctive feature of the Mir manned submersible is its transparent fairing mounted at its nose end.[3] The submersible has a payload of 0.3 metric tons. Its pressure hull is made of martensite-aging steel with a yield strength of 1,600 to 2,000 mPa. The pressure hull has a diameter of 2.1 m. The submersible is equipped with two manipulators and three illuminators.

The successful creation of a manned submersible depends on correct selection of the material of the pressure hull and the propelling plant's power sources. Steel, aluminum, titanium, and acrylic plastic are presently used to manufacture the submersibles' pressure hulls. Steel is used most extensively to manufacture submersibles' hulls. This is because of the high degree of assimilation of the material and its good strength characteristics.

Titanium is a promising material for the manufacture of pressure hulls. When used to replace steel, it reduces a submersible's weight considerably. This was graphically demonstrated when the American manned submersibles Alvin and Sea Cliff were reoutfitted. When titanium is used to manufacture a pressure hull, special attention must be paid to the process used to manufacture the alloys and machine the finished hulls.[1]

New grades of steel with specific strength properties surpassing those of titanium have recently been created. This has made it possible to create pressure hulls for manned submersibles that are just as lightweight as titanium pressure hulls.

Only electric batteries, primarily lead-acid and silver-zinc batteries, have generally been used as primary power sources of the manned submersibles under consideration. Silver-zinc storage batteries are two to three times lighter than lead-acid batters; however, they have a shorter useful life and take longer to charge.[6]

At the present time, the cruising capacity of manned submersibles with respect to habitability is tenfold their cruising capacity with respect to power resources. Power resource may be increased significantly by using new battery systems, electrochemical generators, or other promising power sources.

The greatest practical results with respect to the development of new types of chemical current sources have been achieved in the field of creating electrochemical generators based on a hydrogen-oxygen system (fuel element). Thermal motors using an oxidizing agent (oxygen, hydrogen peroxide) may also be used on manned submersibles. The distinctive feature of the operation of most power plants of this type is the need to eliminate excess waste gases. Piston engines with an external heat supply (Stirling motor) are free of this shortcoming.

After analyzing the design characteristics of research manned submersibles with a diving depth of 3,000 to 6,000 m (see Table 1) and the requirements of the USSR Registry, one may identify the following basic requirements imposed regarding the design of submersibles:

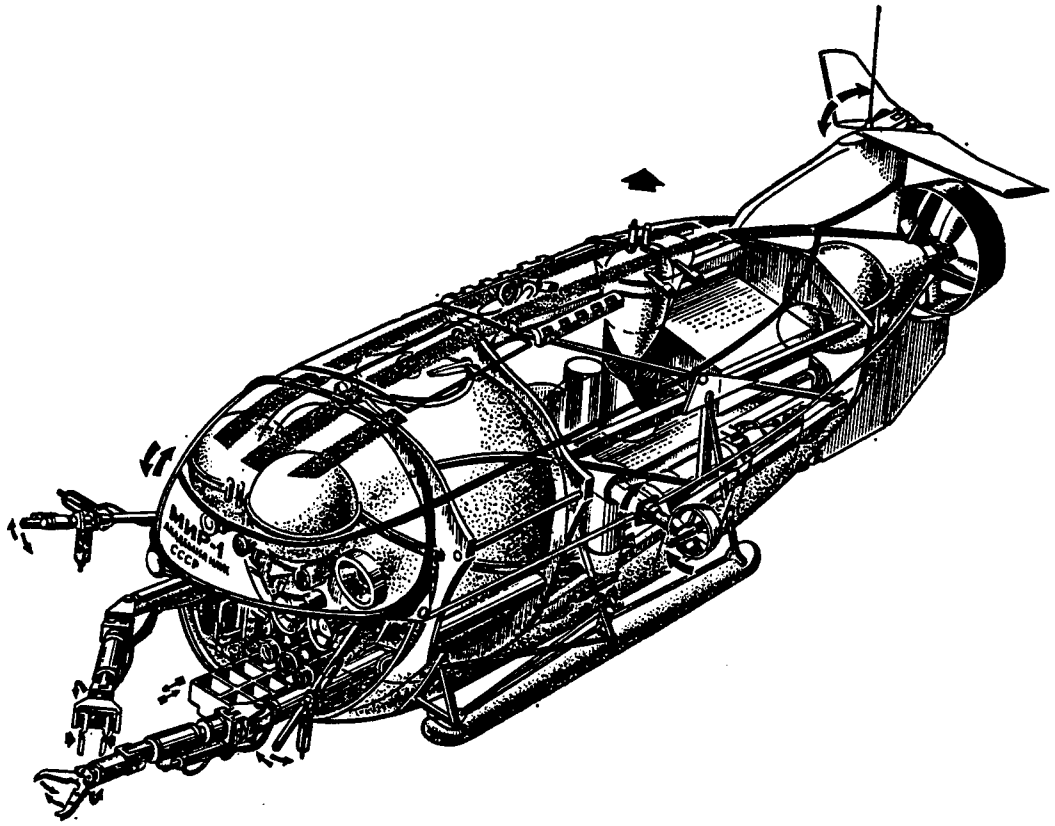

Figure 1. The Mir Type of Manned Submersible With a Diving Depth of 6,000 m Custom Built by Order of the USSR in Finland

—a storage battery is permissible as the main electric power source provided that the emergency storage battery has a power reserve of 72 hours;

—a manned submersible should be equipped with an engine-propelling system for horizontal, vertical, and lateral movement or with universal devices capable of turning in the required direction;

—the life support system should guarantee that people will survive in the submersible in its underwater position for 72 hours, and regeneration and recovery systems should also be present;

—an emergency ballast discharge device should be provided;

—the high-pressure air reserve should ensure complete three-time purging of the ballast tanks at a depth of at least 10 m;

—the navigation equipment should consist of a course indicator, log, depth indicator, acoustic depth finder, inclinometer, trim indicator, sea current velocity indicator, and active sonar;

—a spherically shaped pressure hull with a diameter of 2.1 to 2.2 m that is made of steel or titanium alloy is recommended;

—ratios of $a = L$ divided by the square root of BH (elongation) and $a_2 = H/B$ should be designated when selecting the shape of the outer hull;

—the submersible should have an operating speed of 1 to 2 knots and a maximum speed of 3 to 5 knots;

—the submersible should have a crew size (n_{cr}) of 2 or 3;

—a cruising capacity with respect to power supply (t_a) of 8 to 12 hours is required;

—the submersible should have a payload (P_{pl}) of 0.2 to 0.3 metric tons.

The above basic design requirements for manned submersibles are used as a basis for calculating the normal displacement and main dimensions of the outer hull in a first approximation. The normal displacement of a research manned submersible with a diving depth of more than 2,000 m is determined through the submersible's independent weight P_{in}:

$$D = P_{in}/\eta,$$

where $\eta = 0.13$ to 0.14 is the displacement efficiency.

The portion of the manned submersible's total weight that is independent of diving depth, speed, cruising capacity, and design decisions adopted consists of the payload; crew weight P_{cr}; and weight of the control, navigation, and communications equipment P_{eq}:

$$P_{in} = P_{pl} + P_{cr} + P_{eq};$$

$$P_{cr} = p_{cr}n_{cr} + (p_{peq} + p_{wp}t_a^0)n_{cr};$$

$$P_{eq} = 0.137(H_p/1000) + 0.33,$$

where $p_{cr} = 0.1$ metric tons is the weight of one crew member; $p_{peq} = 0.22$ metric tons is the norm for personal equipment; $p_{wp} = 0.015$ metric tons/(person x days) is the norm for water and provisions; and t_a^0 is the cruising capacity with respect to habitability.

The outer hull's dimensions is determined by the formulas

$$L = \sqrt[3]{\frac{kDa_1^2}{\rho\delta}}; \quad B = L/(a_1a_2^{0.5}); \quad H = a_2B,$$

where $k = 1.84$ to 2.28 is a coefficient allowing for the weight of the ballast tanks and permeable parts; $a_1 = 2.6$ is the length of the pressure hull; $\delta = 0.56$ to 0.66 is the coefficient of the outer hull's total fullness; ρ is the water density; and $a_2 = 1.1$ is the ratio of the outer hull's height to its width.

This analysis of main design characteristics of research manned submersibles with a working diving depth of more than 2,000 m makes it possible to select an optimal design specification and determine normal displacement and optimal dimensions based on the above formulas, as well as to develop a sketch of the submersible's overall layout.

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Production Principles of Self-Propagating High-Temperature Synthesis Extrusion

937F0110A Minsk INZHENERNO-FIZICHESKIY ZHURNAL in Russian Vol 63 No 5, Nov 92 pp 525-537

[Article by V.V. Podlesov, A.V. Radugin, A.M. Stolin, A.G. Merzhanov, Structural Macrokinetics Institute at Russia's Academy of Sciences, Chernogolovka; UDC 621.762:621.7.011(048)]

[Abstract] A new self-propagating high-temperature synthesis (SVS) extrusion method whereby the item structure is formed under high-temperature deformation is discussed and attention is focused on the production aspects of this technology. An attempt is made to explain the possibility of extruding various products at temperatures of close to 1,000° C and on developing special SVS-extrusion equipment. Experimental studies of extrusion conditions are summarized. The dependence of the extrusion fullness, surface quality criterion, and combustion temperature of the compositions on the Ni content, in % by mass, the dependence of the compacted material mass on the delay time for dies with various cone angles, the dependence of the extrusion fullness and surface quality criterion on the die cone angle, the dependence of the surface quality criterion on the delay time at various angles, the dependence of the defective layer on the item diameter, the dependence of the surface quality on the straining degree, the dependence of the extrusion fullness on the plunger speed, and the dependence of the item length on the extrusion pressure are plotted. The advantages of the SVS-extrusion method for making extended refractory products are demonstrated and the possibilities of the method for studying the processes of synthesis, structure formation, and high-temperature plastic deformation are noted. The authors are grateful to S.V. Vedeneyev for describing the characteristics of silicide material extrusion. Figures 9; references 12: 11 Russian, 1 Western.

Structure Formation Patterns of Synthetic Hard Tool Materials During Self-Propagating High-Temperature Synthesis Compaction

937F0110B Minsk INZHENERNO-FIZICHESKIY ZHURNAL in Russian Vol 63 No 5, Nov 92 pp 558-576

[Article by Ye.A. Levashov, Yu.V. Bogatov, A.S. Rogachev, A.N. Pityulin, I.P. Borovinskaya, A.G. Merzhanov, Structural Macrokinetics Institute at Russia's Academy of Sciences, Chernogolovka; UDC 625.762.043:66.046.4]

[Abstract] The new practices for producing synthetic hard tool materials (STIM) by self-propagating high-temperature synthesis whereby the combustion process is combined with compaction of the hot synthesis products are outlined and it is noted that the new method makes it possible to produce the so-called synthetic functionally gradient materials (SiGMa or FGM) whose composition and properties change gradually throughout the volume. The phase composition and original components of STIM and FGM materials are summarized. Attention is focused on the structure formation process in an SHS wave by the quenching method, the structure formation patterns of alloys under SHS compaction, the effect of the ultrasonic field on the alloy structure, and the effect of the initial charge characteristics on the STIM alloy structure. The physical and mechanical properties of FGM alloys are examined and it is demonstrated that the SHS process parameters are interrelated with the structure of the resulting products. This makes it possible to outline possible ways of controlling the process and produce composites with specified structure and properties. Figures 12; tables 6; references 29: 20 Russian, 9 Western.

Synthetic Diamond Behavior Patterns in Self-Propagating High-Temperature Synthesis Combustion Wave

937F0110C Minsk INZHENERNO-FIZICHESKIY ZHURNAL in Russian Vol 63 No 5, Nov 92 pp 577-582

[Article by K.L. Padyukov, Ye.A. Levashov, I.P. Borovinskaya, A.G. Kost, Structural Macrokinetics Institute at Russia's Academy of Sciences, Chernogolovka; UDC 66.09-977:621.921.34]

[Abstract] The effect of the diamond origin, impurity composition, and grain size on its behavior at high temperatures is discussed and the difficulty of using traditional methods for fabricating hard-alloy diamond tools with a hard alloy matrix, especially large tools, prompted an attempt to make a hard alloy diamond material by the self-propagating high-temperature synthesis method. To this end, the AS 20 synthetic powder is used for examining the diamond behavior in the combustion wave using a model Ti-B SHS system as the original composition (Ti+2B+55% Ti). The initial isothermal charge was prepared from TPS titanium powder, amorphous boron, and synthetic AS 20 diamond. The dependence of the combustion temperature and combustion rate on the diamond powder concentration in the charge and the dependence of the graphitization degree and loss of strength of diamond grains on the combustion temperature of the mixture are plotted. The length of diamond particle stay in the heated layer on the combustion front increases as the exothermal mixture is diluted with an inert component. The findings confirm the possibility, in principle, of preserving diamonds and their strength properties during SHS and make it possible to regard this approach is promising for making hard alloy diamond materials. Figures 2; references 14: 12 Russian, 2 Western.

High-Temperature Rheology of Materials Made by Self-Propagating High-Temperature Synthesis

937F0110D Minsk INZHENERNO-FIZICHESKIY ZHURNAL in Russian Vol 63 No 5, Nov 92 pp 593-604

[Article by L.M. Buchatskiy, A.M. Stolin, Structural Macrokinetics Institute at Russia's Academy of Sciences, Chernogolovka; UDC 621.762]

[Abstract] The effect of the hot synthetic product body's microscopic flow ability on implementation of known methods of structural material production by self-propagating high-temperature synthesis prompted attempts to combine the SHS method with all types of plastic working. This prompted the development of a new field—rheosynthesis—whereby all aspects of making products with a specified shape and dimensions or a given porosity can be learned from the patterns of rheological behavior of SHS products in the high-temperature area. The rheological characteristics of SHS materials and viscosimetric flows and rheological variables are examined from a continuum viewpoint allowing for the dependence of the rheological properties of SHS materials on what occurs with their pores and core. The procedure of plotting rheological curves from data on a series of viscosimeter experiments is outlined and rheological curves of a viscous porous material with various densities and viscosimetry characteristics of one-sided compression of pseudoplastic materials are plotted. The effect of the nonuniform porosity, external friction, and nonisothermal SHS conditions on the flow behavior is examined in detail. The issue of SHS material rheometry is addressed; for illustration, the compaction kinetics of a molybdenum disilicide-based composition at various delay times from the initiation moment to the pressure application moment are described. Processing of kinetic data demonstrates that all findings are consistent with a power series of the rheological state equation. Figures 8; references 23: 18 Russian, 5 Western.

Rheodynamics and Heat Exchange Under Hot Compaction of Powder Materials

937F0110E Minsk INZHENERNO-FIZICHESKIY ZHURNAL in Russian Vol 63 No 5, Nov 92 pp 612-622

[Article by L.S. Stelmakh, N.N. Zhilyayeva, A.M. Stolin, Structural Macrokinetics Institute at Russia's Academy of Sciences, Chernogolovka; UDC 532.135]

[Abstract] The flow dynamics (rheodynamics) models whose principal parameters are the macroscopic density, rate, and stresses in the materials and their use for establishing the dependence of the porous body density on the applied pressure, i.e., the kinetics of its compaction, are discussed and the results of mathematical modeling of the deformation and thermal processes of self-propagating high-temperature synthesis compaction are reviewed. The problem of one-sided compaction and extrusion of powder materials is solved analytically, making it possible to determine various compaction and

extrusion parameters at a qualitative level and determine their criterial realization conditions. The effect of the temperature and heat exchange nonuniformity on the material compaction and extrusion patterns is analyzed analytically. To this end, analytical models of hot powder material compaction are constructed and the density and rate distribution at various moments, the dependence of the maximum limit of density on the logarithm of the ratio of the extrusion and compaction time, and the domain of compact products on the plane of the Fourier delay and Biot parameters are plotted. Nonisothermal rheodynamics of SHS compaction and viscous compressible material extrusion are considered. Figures 6; references 17.

On Periodic Nature of Density's Dependence on Weight in Compaction of Thin Layers of Certain Powders

937F0110F Minsk INZHENERNO-FIZICHESKIY ZHURNAL in Russian Vol 63 No 5, Nov 92 pp 630-635

[Article by M.A. Ponomarev, A.S. Shteynberg, Structural Macrokinetics Institute at Russia's Academy of Sciences, Chernogolovka; UDC 621.762]

[Abstract] Structural self-ordering during the compaction of thin layers of certain powders is discussed and the compaction patterns of thin layers of the Ti+2B powder used for producing titanium diborides by self-propagating high-temperature synthesis are examined. To this end, samples are made from PTK titanium and amorphous B99-A boron in a stoichiometric ratio. The dependence of the relative compact density on the bulk mass and number of compacting strikes on the plunger is plotted and the maximum:minimum density ratios for various numbers of layers are summarized. The formation of an ordered structure from powder particles under compaction is examined and a periodic dependence of the compacted product density on the sample weight is established; on the other hand, the dependence of the product density on the number of compacting strikes against the plunger is step-wise. The above periodic dependence can adequately explain the observed possibility of the ordered structure formation from relatively large Ti particles surrounded with finely disperse B. This is confirmed by the qualitative and quantitative consistency of the experimental data with the packing density characteristics of spheres arranged into tetrahedral and octahedral packed structures. In addition, the step-wise dependence of the compacted product density on the number of compacting impulses can also be explained in the framework of this model. Figures 5; tables 1; references 6.

Self-Propagating High-Temperature Synthesis Extrusion of Electrode Materials and Their Use for Electrospark Alloying of Steel Surfaces

937F0110G Minsk INZHENERNO-FIZICHESKIY ZHURNAL in Russian Vol 63 No 5, Nov 92 pp 636-647

[Article by V.V. Podlesov, A.M. Stolin, A.G. Merzhanov, Structural Macrokinetics Institute at Russia's Academy of Sciences, Chernogolovka; UDC 621.9.048]

[Abstract] The use of electrospark alloying (EIL) based on the anode material transport principle to the cathode in an electric discharge are discussed and it is noted that existing practices involve a large number of operations many of which are complicated, energy-consuming, and take a long time to perform. This prompted a principally new approach to the process of electrode-making using self-propagating high-temperature synthesis extrusion which greatly simplifies production and shortens the material synthesis and product molding to a few seconds (from several hours) in a single production cycle. The SHS extrusion method used for making electrode materials from various transition metal carbide- and boride-based hard alloy components is described. The specific features of SHS extrusion of electrodes, the composition, microstructure, and properties of electrode materials and alloyed layers, and the experience of practical applications of SHS electrodes are outlined. The resistance of electrospark alloyed electrodes to wear and corrosive media is summarized. The new method also makes it possible to shorten the time from the concept of new electrode materials to their actual implementation since only the SHS stage proper must be optimized. In addition, the requirements imposed on the purity and quality of the original source powders can be relaxed. Figures 9; tables 8; references 16.

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